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College of William and Mary - Virginia Institute of Marine Science

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JUVENILE PELAGIC FISH COMMUNITIES IN THE MATTAPONI AND PAMUNKEY RIVERS, VIRGINIA

A Thesis
Presented to
The Faculty of the School of Marine Science
The College of William and Mary in Virginia

In Partial Fulfillment
Of the Requirements for the Degree of
Master of Arts

by
Steffany I. Dawson
1992

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Master of Arts

Steffany Dawson

Approved, December 1992

Joseph G. Loesch, Ph.D.,
(Chairman)

James A. Colvocoresses, Ph.D.

Robert J. Diaz, Ph.D.

Suzette M. Kimball, Ph.D.

Gene M. Silberhorn, Ph.D.

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ABSTRACT

Data from the 1983-1987 and 1991 *Alosa* summer surveys were used to assess the temporal and spatial relationships of the juvenile pelagic fishes in the Mattaponi and Pamunkey rivers. Fifteen river miles consisting of three strata on the Mattaponi were sampled for five weeks, and twenty river miles consisting of four strata were sampled for four weeks on the Pamukey using a pushnet. Cluster analysis produced different species groupings for the two rivers based on abundance. The biggest difference in species abundance was in the number of blueback herring. Bluebacks were much more abundant on the Pamunkey probably because the environment is more suited to their spawning needs. The community structures of the two rivers appear to be influenced by environmental factors rather than competition or predation of a key or cornerstone species. The communities were considered to be persistent and deterministic based on the Kendall's rank correlation, fidelity, and diet partitioning. Diversity varied from year to year due to the variation in year class strength in the most dominant species, blueback herring. The spatial scales of this study were too small to detect distinct fish zones or a downstream addition of species. A logistic regression model was run with the null hypothesis that strata volume has no effect on population density. When strata volume affected population density, as strata volume increased population density decreased for all species except blueback herring in 1986 and spottail shiner in 1983 on the Pamunkey.

JUVENILE PELAGIC FISH COMMUNITIES IN THE MATTAPONI AND PAMUNKEY RIVERS, VIRGINIA

INTRODUCTION

A debated question in stream fish ecology is whether or not a community is stochastic, changing from year to year due to environmental variation, or if it is deterministic, remaining the same over time (Heins and Matthews 1987; Moyle and Cech 1988). Many researchers hypothesize that stream communities are too unstable to allow species to establish set communities that will last over time (Harrell 1978; Grossman et al. 1982; Ross and Baker 1983; Schlosser 1985). Others have found that communities can bounce back from severe perturbations (Moyle and Vondracek 1985; Matthews 1986).

Moyle and Vondracek (1985) define the characteristics of species in stochastic communities and list the characteristics that Grossman (1982) found for deterministic communities. These characteristics are: 1) Species in stochastic communities do not persevere through time (Moyle and Li 1979; Grossman et al. 1982; Sclosser 1982) while those in deterministic communities do: 2) Species in stochastic communities tend to be morphologically similar whereas those in deterministic communities are not: 3)

Species in stochastic communities are not partitioned by habitat or diet (Matthews et al. 1982; Schlosser and Toth 1984) as are species in deterministic communities: 4) Species in stochastic communities can't recover from ecological or natural disaster while those in deterministic communities can.

Grossman et al. (1982) point out that the characteristic of persistance is a major factor in determining whether or not a given community is deterministic or stochastic. Connell and Sousa (1983) define persistence of a community as when the species or populations in a certain area don't become extinct over a certain time period or recover by reinhabitating the system within a certain period if they did become extinct from that area. They recommend that the species in the community should be studied for at least one turnover of individuals in the longest lived species in the community and that the study area be an appropriate area to find the minimum stability of the community. They contend that if the study area is not large enough, the study may show no persistence for the community when it may indeed be persistent, while if the study area is too large, the study could show persistence when the community may not be persistent.

The distribution of the species in the stream or river is also of ecological importance. According to Rahel and Hurbert (1991) there are two main hypotheses of how communities are longitudinally distributed. The first hypothesis is that there are distinct biotic zones (Huet 1959; Balon and Stewart 1983; Moyle and Herbold 1987). Huet (1959) found four major fish zones in Western European streams; the trout zone; the grayling zone; the barbel zone; and the bream zone. The second hypothesis is that from upstream to downstream there is a continuous increase in community complexity by an addition of species (Sheldon 1968; Jenkins and Freeman 1972; Evans and Noble 1979). Rahel and Hurbert (1991) found that on large spatial scales the zone hypothesis was true and that within the zones the addition hypothesis was true.

This paper attempts to address the issues of how juvenile pelagic fish communities in two Virgina rivers (the Mattaponi and the Pamunkey) change with time and how the fish are distrubuted in these two rivers. In the first part of the present study, the communities between the Mattaponi and the Pamunkey rivers were compared. In the second part the question of persistence in juvenile finfish estuarine communities was studied. In the third part the questions of how the distribution of species changes from upstream to downstream and how the distribution of species within the strata changes from year to year was addressed.

Specific questions addressed were: 1) are the different river communities similar to each other? 2) does the surface community of night pelagic freshwater juvenile fishes change with time? 3) does the diversity of this community change with time? 4) is this community deterministic or stochastic? 5) Is there a downstream addition of species or are there distinct fish zones? and, 6) does the catch per unit effort (CPUE) of a species change from upriver to downriver as the volume of the river increases?

OBJECTIVES

The first objective was to examine how the river surface fish communities change with time. The null hypothesis was that there was no change in community structure through time. The second objective was to see how the species distributions changed temporally and spatially. The third objective was to make a comparison between the communities found in the Mattaponi and Pamunkey rivers.

MATERIALS AND METHODS

Data Collection:

The Mattaponi and Pamunkey rivers (Fig. 1) were chosen for this study because the necessary data could be obtained from juvenile Alosa index surveys (conducted in the summers of 1983-1987, 1991). The surveys were made at night of the near surface (0 to 1.5m) juvenile fish community. The surveys were conducted following a stratified random sampling plan (SRS) which divided the rivers into a series of 9.3 km strata which were then divided into five, 1.9 km substrata and each substrata was further divided into 3 blocks (left shore, channel, and right shore). To pick the sampling stations three substrata were randomly chosen from each stratum and then one block was randomly chosen from each of the three substratas. Therefore, each stratum was divided into 15 cells and 3 cells were sampled on each cruise.

The Mattaponi River was sampled for five weeks each summer from river mile 59 to 45 which is 15 nautical miles consisting of three of the 9.3km strata. The Pamunkey the river was sampled for four weeks each summer from river mile 69 to 50 which is 20 nautical miles consisting of four of the 9.3km strata. Diversity indices were calculated to compare diversity between the two rivers, to see how diversity changes with time in the estuary, and to compare diversity between upstream and downstream distributions. A Kendall's W of concordance was used to compare agreement of species rankings between the years to determine if the communities were deterministic or stochastic. Cluster analysis was run to find the most alike years and species, and to group together the most alike species found in each stratum. Nodal analysis was used to find the constancy and fidelity of the species and year groupings and the species and strata groupings. Logistic regression was used to compare the changes in distribution of a particular species in the strata for a year and within the year.

A bow mounted 1.5m X 1.5m rigid framed pushnet (12.7mm mesh) was used to take samples of the surface community in tidal freshwater (Kriete and Loesch 1980). At each station the pushnet was lowered until the top of the frame was just below the surface, then a 5 minute sample was taken at an absolute towing speed of 1 m/s which was achieved by keeping the RPMs constant at 1200. Catch data were later adjusted to a constant volume of water filtered (see below).

Preservation and Identification:

Fish were preserved in 5% borax buffered formalin and taken back to the lab. There the samples were rinsed, and put into 70% ethanol for storage. Later they were identified using the keys in Boschung et al. (1983), Robins et al. (1986), Hildebrand and Schroeder (1972), Wang and Kernehan (1979), and Lippson and Moran (1974).

Statistical Analysis:

Species abundances were calculated by using catch per unit of effort (CPUE) for each tow. Flowmeters mounted at midheight and one third width were used to calculate the volume of water passing through the net. The catches were adjusted to a standard volume of 655 m^3 based on the flowmeter readings (Loesch et al. 1982). The standardized catch for each species was summed for the year and then divided by the number of tows done on the river for the year to give the CPUE for the temporal analysis. This means that all the weeks and all river strata were pooled into one species list for each year. The total number of tows done per year on the Mattaponi was 45. The total number of tows done on the Pamunkey per year was 48. For the spatial analysis the standardized catch for each stratum were pooled together and then divided by the number of tows per strata to give the CPUE of the strata. Fifteen tows per strata per year were taken on the Mattaponi and twelve tows per strata were done on the Pamunkey each sampling season. The recommendations of Ludwig and Reynolds (1988) were followed in the analysis of the communities.

Diversity indices have been used to see if a community changes with time. Margalef (1969), Lie and Evans (1973), Harrell (1978), and Schlosser (1982) all used diversity indices in this fashion. However, as Grossman (1982) points out, diversity indices can be misleading because two communities can have the same diversity measure but a different number of species since diversity is based on both richness and evenness. Thus, richness and evenness measures shoud be included in this type of study. Diversity analysis can also be used to compare changes in fish distribution from upstream to downstream (Sheldon 1968; Jenkins and Freeman 1972). Diversity was compared between the two communities also.

Diversity was compared from year to year, from stratum to stratum and between rivers. Three diversity indices were calculated to ensure that this study can be compared with others. Hill (1973) proposed a method to do this. His basic formula is:

$$N_A = \sum_{i=1}^{S} (P_i)\ 1/(1 - A)$$

where

P_i is the proportion of individuals belonging to the i^{th} species and A is the order of the diversity number.

When A = 0, Hill's basic formula is equal to the total number of species S found in the community:

$$\text{Number 0: } N_0 = S$$

When A = 1, Hill's basic formula is related to the Shannon-Weaver index of diversity H':

$$\text{Number 1: } N_1 = e^{H'}$$

where H' is:

$$H' = -\sum_{i=1}^{S^*} (P_i \ln P_i)$$

where P_i is the same as above and S^* is species with known proportional abundances.

When A = 2, Hill's basic formula is related to the Simpson index of diversity:

$$\text{Number 2: } N_2 = 1/\lambda$$

where λ is:

$$\lambda = \sum_{i=1}^{S} \frac{n_i(n_i - 1)}{n(n-1)}$$

where n is the total number in a sample and n_i is the number of individuals in the i^{th} species.

Species richness was calculated using the Margalef

(1958)

index.

$$R = \frac{S - 1}{\ln(n)}$$

S = total number of species in the community

n = total number of individuals in the community

Next evenness was calculated.

$$E = \frac{N_2 - 1}{N_1 - 1}$$

Three different data subsets were clustered (Boesch 1977; Ludwig and Reynolds 1988). The first data set used in the cluster analysis compared the similarity between the species CPUE from year to year for each river. The second data set clustered compared the similarity between species CPUE from year to year for both rivers. The third data set used in the cluster analysis compared the similarity between the species CPUE from river stratum to river stratum. All of the clusters were exclusive, intrinsic, hierarchical, agglomerative, and combinatorial with flexible linkage (Beta= -0.25). The data were logtransformed. The resemblance function used in the cluster analysis was the Bray and Curtis (1957) index of similarity.

$$PS_{jk} = \frac{2\Sigma \min(X_{ij}, X_{ik})}{\Sigma (X_{ij}+X_{ik})}$$

where

PS_{jk} is the percentage similarity between year or stratum j and year of stratum k.

X_{ij} is the abundance of the i^{th} species in the j^{th} year or stratum.

X_{ik} is the abundance of the i^{th} species in the k^{th} year or stratum.

Both normal and inverse clusters were run and the data were then put into a two-way table and a nodal analyses was run (Boesch 1977). Constancy and fidelity matrices were formed. Constancy is the number of occurrances in a cell divided by the total number of occurances. Fidelity is the constancy of a certain species in a group divided by the constancy of all the species groups (Boesch 1977).

A Kendall's W of concordance was used to determine if the ranks of species were significantly correlated. If the assemblage of species was correlated, the community was considered to be deterministically derived; conversely if the assemblage of species was not correlated, the community was considered to be stochastically regulated (Grossman et al. 1982). The Kendall's W of concordance test has been used in a number of community studies for this purpose (Lie and Evans 1973; Grossman 1982; Grossman et al. 1982; Schlosser 1985; Matthews 1986). The top ten dominant species which were determined by taking an average of the CPUE for all the species for the years 1983-1987 were ranked and tested for correlation. Only the consecutive years were tested and thus the 1991 data were not included for this test.

For the spatial study, a logistic regression was used to compare and model the strata. An ordinal logistic regression (Imrey et al. 1981; Imrey et al. 1982; Stanish 1986; Agresti 1990) was run for the top three dominant species on each river using one species at a time. The CPUE in the species of interest and the CPUE of the rest of the species were the response variables. The volume of each stratum was the explanatory variables. The null hypothesis was that species density does not change as the volume of the strata changes.

History of the data set:

As previously stated, the data were not collected for the sole purpose of community analysis, but for the juvenile *Alosa* index. This was not a problem to be overcome, but it was important to keep in mind. Lengths for the data from 1983-1987 were not recorded for the species, so I had to assume that the fish caught in the net were recruited to the gear. I believe this was a reasonable assumption since most of the species are recruited to the gear by the first or second week of June. This assumption was tested by plotting length frequencies of the top three dominant species collected on each river in 1991. If this assumption was incorrect the CPUE was overestimated.

The results of the length frequency plots from the three dominant species found in each river in 1991 are shown in Figures 2 and 3. The cutoff length used for alosids to be considered to be recruited to the gear used is 27 mm as determined by Loesch and Kriete (1983). Most of the fish collected were of the same fusiform type shape as the Alosids (except hogchokers) and thus 27 mm is assumed to be a correct cutoff length. The plots of the 1991 data show that most of the fish caught were larger than 27 mm and since the 1991 data were collected at the same time of year as the data from the earlier years the assumption that all the fish collected were recruited to gear appears to be reasonable.

The CPUE for all the species were drastically reduced in 1991 (Fig. 10 and 11). This could be the result of a bad year class caused by environmental conditions. There was a necessary vessel replacement in the 1991 survey. However, 175 paired trials with the old and new vessels indicated no significant difference in the fishing power (Dixon and Loesch 1990). Thus the vessel change is probably not the reason for the lower CPUE findings.

RESULTS

TEMPORAL

Table 1 lists the species found in the Mattaponi and Pamunkey rivers during the study. A total of 37 species were collected from both rivers, 35 were found on the Mattaponi and 28 were found on the Pamunkey. Thus, 9 species were exclusive to the Mattaponi (banded sunfish, black bullhead catfish, black crappie, bluespotted sunfish, brown bullhead catfish, longnose gar, redbreast sunfish, rough silverside, and yellow perch) and 2 species were found only on the Pamunkey (bridle shiner and spot).

Catch per unit effort (CPUE) of each species found in each river clearly show which species dominated each summer season (Figs. 4, 5). A species was considered to be the sole dominant if it was greater than or equal to 50% of the composition of the community. For the Mattaponi in 1983, 1986, 1987, and 1991 there was more than one dominant species. American shad (33%), blueback herring (28%), and white perch (16%) all co-dominated in 1983. In 1986 there were three co-dominant species American shad (34%), blueback herring (32%), and spottail shiner (14%). During 1987 American shad (32%) and white perch (18%) were the two most dominant species. Four species co-dominated in 1991 blueback herring (27%), bay anchovy (26%), American shad (17%), and spottail shiner (10%). In 1984 and 1985 blueback herring were the single most dominant species. On the Mattaponi the most abundant species fluctuated between American shad and blueback herring and there was a fluctuation from single dominant species years to co-dominant species years.

The years 1983-1987 (78%,71%,74%,50%,88%, respectively) were all years in which blueback herring were the single most dominant species for the Pamunkey (Fig.5). However, five species co-dominated in 1991 blueback herring (31%), spottail shiner (17%), striped bass (15%), American shad (14%), and bay anchovy (12%). On the Pamunkey blueback herring were the most abundant species every year and there was only one year that several species co-dominated 1991.

Species diversity, evenness, richness, and total CPUE are shown in Table 2 for both the Mattaponi and Pamunkey. The highest number of species found on the Mattaponi was 24 in 1985 and the lowest was 17 in 1991. For the Pamunkey the highest number of species was 19 which occurred in 1983, 1984, and 1986. The lowest number of species found on the Pamunkey was 16 which occurred in both 1985 and 1987.

For both rivers the diversity indices varied from year to year and there didn't appear to be a pattern. On the Mattaponi diversity decreased till 1986 then it increased till 1987 and then it decreased in 1991. For the Pamunkey diversity increased and then decreased every other year consecutively and then increased in 1991. Diversity was highest on the Mattaponi in 1987 and on the Pamunkey in 1991. Diversity was high for both rivers in 1986 and 1991 when there was a codomination of species for each river.

Richness varied slightly and evenness varied a lot for both rivers. Richness and evenness were high on the Mattaponi in 1983, 1986, 1987, and 1991 which were the years that more than one species dominated. On the Pamunkey richness and evenness were highest in 1991 which was the year with the most codominance for that river. Overall richness and evenness were higher on the Mattaponi than on the Pamunkey.

For the temporal cluster analyses species that only occurred in one year were dropped from the cluster. Species groups were made on the basis of abundance. On the Mattaponi 24 species occurred in more than one year (Fig. 6a). The species were separated in eight groups and the years were clustered into two.

<u>MATTAPONI SPECIES GROUPS</u> (Fig. 6a)

A Alewife/white catfish/Eastern silvery minnow: These species were the third, fourth and fifth dominant species for this river.

B Blueback/American shad: These species were the first and second dominant species on the river.

C White perch/channel catfish/spottail shiner/bay anchovy: These species were all present in medium numbers.

D Striped bass/inland silverside/banded killifish/Atlantic menhaden: These species all occurred once in 1984 and 1985.

E Tessellated darter/brown bullhead catfish/hogchoker/ Atlantic needlefish: These species were all present in low numbers.

F Bluegill: This species only occurred in 1983, 1986, and 1987.

G Black crappie/hickory shad: These species only occurred in two years.

H Pumpkinseed/green sunfish/largemouth bass/banded sunfish: These species were all rare.

<u>MATTAPONI YEAR GROUPS</u> (Fig 6b)

I 1983/1987/1986/1991: These were the years when more than one species dominated.

II 1984/1985: Bluebacks were the sole dominant species on the Mattaponi in these years.

Constancy was very high in both year groups for species groups A through E (Fig 7a) and these species were found in the river all the years of the study. Species groups F had higher constancy in the co-dominating years than in the years blueback herring dominated. Species group G had a higher constancy during the blueback dominating years. Species group H had moderate constancy in both year groups. Fidelity was low or negative for species groups A through F, and H for both dominating and codominating year groups which means that these species groups weren't restricted to certain year groups (Fig. 7b). Species group G had a higher fidelity in year group II than in year group I.

On the Pamunkey 17 species occurred in more than one year (Fig. 8a). The species were divided into nine groups and the years formed two.

<u>PAMUNKEY SPECIES GROUPS</u> (Fig 8a)

A Alewife/American shad/Atlantic menhaden: These species have very similar body types and were present in medium numbers.

B Bay anchovy/spottail shiner/Eastern silvery minnow: These species were present in medium numbers.

C Blueback herring: This was the most dominant species on this river. It had a much higher abundance than all the other species.

D Striped bass: This species was present in every year and had a greatly increased abundance in 1991.

E White perch/inland silverside/white catfish: These species were eighth, ninth and tenth in dominance.

F Channel catfish/satinfin shiner: These species were all present in low numbers.

G Tesellated darter/Atlantic needlefish: These species were all rare.

H Hogchoker: This species was present every year except in 1984.

I Banded killifish: This species only occurred in three of the years 1983, 1984, and 1991.

PAMUNKEY YEAR GROUPS (Fig. 8b)

I 1983/1984/1986/1985/1987: In all these years the blueback herring dominated.

II 1991: This year had five co-dominant species.

Constancy was very high in both year groups for species groups A though E and group H (Fig. 9a). Species groups F and G had a higher constancy in year group I than in year group II. Species group I had a higher constancy in year group II. Fidelity was low or negative for all the species groups except I, so once again most of the species groups weren't limited to a certain year group (Fig. 9b).

The cluster combining the Mattaponi and the Pamunkey included 29 species which occurred more than once (Fig. 10a). There were six species groups and three year groups.

MATTAPONI AND PAMUNKEY SPECIES GROUPS (Fig. 10a)

A Alewife/American shad/Eastern silvery minnow/blueback/spottail shiner/bay anchovy/Atlantic menhaden: This group encompasses most of the top ten species from each river.

B Striped bass/white perch/white catfish/inland silverside/channel catfish/satfin shiner: These species were all present in medium numbers.

C American eel/pumpkinseed: These species were only present in the years where more than one species dominated.

D Tesellated darter/banded killifish/hogchoker/Atlantic needlefish/brown bullhead catfish/bluegill/black crappie/hickory shad: These species occured in low numbers.

E Largemouth bass/smallmouth bass/banded sunfish/green sunfish: The species in this group occured mostly in the Pamunkey in 1985.

F Chain pickerel/golden shiner: These species were present only in 1984 on both rivers.

<u>MATTAPONI AND PAMUNKEY YEAR GROUPS</u> (Fig. 10b)

I MP1983/MP1987/MP1986/MP1991/PM1991: During these years several species co-dominated.

II MP1984/MP1985: These were the years that blueback herring dominated on the Mattaponi.

III PM1983/PM1984/PM1986/PM1985/PM1987: During these years blueback herring dominated the Pamunkey river community.

Species groups A and B have very high constancy in all the year groups (Fig 11a). Group C had moderate constancy in year group I. Constancy was highest for species groups D, E, and F in year group II the Mattaponi blueback dominating years. Species group C was moderately limited to year group I (Fig. 11b). Species group E and F were limited to year group II.

The ten most abundant species found in each river in the years 1983-1987 that were used in the Kendall's rank test are shown in Table 3. Although they are ranked in different orders the top ten species for both rivers are basically the same with one exception. Atlantic menhaden is included in the top ten on the Pamunkey and Channel catfish is included on the Mattaponi. Blueback herring were ranked number one for both rivers. Tables 4a and 4b show the rankings used in the Kendall's test. The results of the test show that the rankings of the species were significantly correlated and thus the assemblages on both rivers are considered to be deterministically derived (Table 5).

The CPUE for the top three species on each river (as shown in Table 3) was plotted (Figs. 12 and 13). On the Mattaponi the CPUE for the bluebacks, American shad, and

Eastern silvery minnows all appear to be decreasing. In 1984 all three species had a very high CPUE. On the Pamunkey the CPUE for the bluebacks fluctuates every other year but is very low in 1991. Spottail shiners had a very high CPUE in 1986 but every other year it stayed basically the same. The CPUE for the Atlantic menhaden increased till 1985 then it decreased.

SPATIAL

Diversity varied inconsistently from upstream to downstream on both rivers (Table 6). On the Mattaponi in 1983, 1984, 1987, and 1991 diversity increased and then decreased going downstream. In 1985 diversity decreased and then increased. Diversity increased in 1986. On the Pamunkey diversity decreased then increased then decreased again in 1983 and 1984 going downstream. In 1985 and 1987 diversity decreased and then increased. Diversity increased and then decreased in 1986 and 1991. Tables 6 and 9 lists the number of species found in each strata. There does not appear to be any distinct fish zones like found by Huet (1959), Balon and Stewart (1983), and Moyle and Herbold (1987). Nor does there appear to be a downstream addition of species which Sheldon (1968), Jenkins and Freeman (1972) and Evans and Noble (1979) all found. In Table 9 which shows the number of species found in each strata from all six years of the study combined, the number of species decreased going downstream for both rivers. Table 6 which shows the number of species found in each strata for each individual study showed no set pattern. The spatial scales of this study may not have been large enough to detect distinct zones or an addition of species. The area sampled were all basically the same type habitat.

The species groups resulting from the spatial cluster that combined all six years are shown below. Both rivers had seven species groups. The spatial analysis dendograms from the six separated sampling seasons was compared to the groupings from the combined cluster (Fig. 14 and 16).

<u>MATTAPONI SPECIES GROUPS</u> (Fig. 14)

A Alewife/Eastern silvery minnow/white catfish/white perch/spottail shiner: These species were all present in large numbers. In 1983 this group clustered out together with the exception of white perch. Every other year the group was split up with only two species co-occurring together.

B Blueback/American shad: The top two dominant species make up this group. Both were found together in 1983, 1985, 1986, and 1991. In 1984 and 1987 they were separated.

C Striped bass/bay anchovy/Atlantic menhaden/inland silverside: These species all had a higher abundance in stratum III than in strata I or II. This group was clustered near each other in 1985, 1986 and 1991. In the other years the species were separated in the dendograms.

D Hickory shad/black crappie/banded sunfish/largemouth bass/tessellated darter/banded killifish/black bullhead catfish: Low numbers of these species were found in all three strata. This group was never found together in any of the years and usually only two members of the group were found each year.

E Brown bullhead catfish/bluegill/redbreasted sunfish/hogchoker/Atlantic needlefish: There was one occurance of these species in each stratum. This group was also never found grouped all together but two species were clustered together in 1983, 1986, and 1987.

F Pumpkinseed/green sunfish/rough silverside/smallmouth bass/bluespotted sunfish: These species were mostly present in stratum II. Some members of this group were clustered together in 1983, 1985, and 1986. None of these species were found in 1984, 1987, and 1991.

G American eel/longnose gar/chain pickerel/golden shiner/satinfin shiner/yellow perch: This group was only found in stratum 1. No members of this group were found in 1986, 1987, and 1991. This group clustered together in 1984 except for two species. In 1983 only American eel was present and in 1985 only satfin shiner was present.

<u>MATTAPONI STRATA GROUPS</u>

I 59-55: These are the upper river miles.

II 54-50: These are the middle river miles.

III 49-45: These are the lower river miles.

Species groups A, B, C, and E had very high constancy in all three strata groups (Fig. 15a). Group D had higher constancy in strata groups I and II than in three. Constancy in group F was highest in strata group II and constancy in group G was highest in strata group I. Species group F had moderate fidelity in stratum II while group G had high fidelity in stratum I (Fig. 15b).

<u>PAMUNKEY SPECIES GROUPS</u> (Fig. 16)

A Alewife/Eastern silvery minnow/spottail shiner/American shad/blueback: These species were all present in high abundance in all the strata. These species were joined or were close together in all the years except 1987 and 1991.

B Striped bass/white catfish/white perch/inland silverside/bay anchovy/Atlantic menhaden: This group had a higher abundance in strata III and IV than in strata I and II. These species clustered near each other in 1986 and 1987. In 1984 and 1991 they were clustered into two groups. The species were separated in 1983 and 1985.

C Channel catfish/satinfin shiner: These species were present in medium abundance in all four strata. Channel catfish were absent in 1984 and 1985. Satinfin shiner was absent in 1991. In 1986 both species were grouped together. In 1983 and 1987 they were separated.

D Tessellated darter/hogchoker/Atlantic needlefish/green sunfish: This group was present in low abundance. In 1983 and 1986 these fish were all close together with the exception of the hogchoker. Tessellated darter was the only member of the group present in 1984. The other 3 years the species were all separated in the dendogram.

E Hickory shad/bluegill/spot/banded killifish: These species were only found in stratum IV. Only one of these species were present each year except in 1984 and 1985. Hickory shad and banded killifish were clustered together in 1984. None of these fish were present in 1985.

F American eel/bridle shiner/pumpkinseed/largemouth bass/smallmouth bass: These species were present only in stratum I. No members of this group were found in 1984, 1985, or 1987. Only bridle shiner was present in 1986. In 1983 and 1991 only two species were present and they clustered near each other.

G Golden shiner/chain pickerel: Both of these fishes were mostly caught in stratum II. These two species clustered together in 1984. They were not present in any other years.

PAMUNKEY STRATA GROUPS

I 69-65: These are the upper river miles.

II 64-60: These are the upper middle river miles.

III 59-55: These are the lower middle river miles.

IV 54-50: These are the lower river miles.

Constancy was high in all four site groups for species groups A and B (Fig. 17a). Species groups C and D both had higher constancy in site groups I, II and III than in site group IV. Constancy was highest for species group E in stratum IV and for species group F in stratum I. Group G had very high constancy in site group II and high constancy in site group I. Fidelity was very high for species group E in strata group IV and for species group F in strata group I (Fig. 17b).

Logistic regression model were fit to test the null hypothesis that volume of a stratum has no effect on population density (Table 7,8). Models for Atlantic menhaden were saturated. A saturated model is one in which a zero value occurs in one of the cells of the test and no conclusions can be drawn from it.

For all species and years where the logistic regression model fit as stratum volume increased the population density decreased, except for blueback herring in 1986 and spottail shiners in 1983 on the Pamunkey river. In those two cases as stratum volume increased population density increased also.

The slopes from the significant models were plotted along with their standard error range (Figs. 18,19). On the Mattaponi for the bluebacks the slope remained basically the same and thus the change of population density with strata volume was the constant for the three years the model fit. For American shad and Eastern silvery minnow the slopes were different but their ranges all encompassed part of the same values. Therefore it can be concluded again that the change of population density with strata volume was the same for the years the model fit. On the Pamunkey the slope ranges overlapped, thus change in density with strata volume for spottail shiners were similar for 1983 and 1991, and for 1984 and 1985. Bluebacks on the Pamunkey had a postive slope the one year the model fit while bluebacks on the Mattaponi always had a negative slope. Thus, the change in blueback density with strata volume may be different for the two rivers.

DISCUSSION

TEMPORAL

Similar species were found in the Mattaponi and Pamunkey (Table 1), but their abundances differed between rivers. The Mattaponi, the Pamunkey, and the combined clusters, which were based on species abundance, formed different species groupings (Figs. 6a, 8a, and 10a). Thus it might be concluded that even though the species present on both rivers are essentially the same, the species could be interacting differently with each other on each river system. For example, on the Pamunkey blueback herring was the most abundant species each year while on the Mattaponi the most abundant species fluctuated between blueback herring and American shad (Fig. 4,5). The greatest difference in abundance of species between the two rivers was in the number of blueback herring. Also, more species were found on the Mattaponi than on the Pamunkey. Therefore, the two communities have different structures but the structures are formed by the same process.

The two main hypotheses or factors that control community structure described by Mahon and Smith (1939) are;

the community assemblage is controlled by environmental gradients; or the community of species regulates itself through predation and/or competition by a key or cornerstone species. Both the Mattaponi and Pamunkey river communities were appeared to vary with environmental factors which agrees with what Mahon and Smith (1989) found for a fish benthic community.

The Pamunkey is a wider, longer river with greater flow (Fig. 20, Table 7). Blueback herring, the most abundant species found on the Pamunkey each year, spawn in lentic waters in more northern latitudes (Loesch and Lund 1977; Loesch 1987). A plausible reason more bluebacks are found on the Pamunkey than on the Mattaponi is because the Pamunkey river has a greater rate of flow which the bluebacks like for spawning. Massman (1953) also found more bluebacks on the Pamunkey and suggested that more bluebacks spawn on the Pamunkey.

The Mattaponi River is smaller and shallower than the Pamunkey and the salinity encroachment goes further upstream. When the tows were taken on the Mattaponi River more of the total volume of the river was sampled. This could be why more species were found on the Mattaponi than on the Pamunkey.

These communities do not appear to be controlling themselves through species competition. The top two abundant species found in each river are not reported to compete for food. On the Mattaponi the top two species are juvenile blueback herring, which feed on planktonic organisms and crustaceans (Davis and Cheek 1966; Domermuth and Reed 1980), and juvenile American shad which feed on terrestrial insects (Massman 1963; Domermuth and Reed 1980). Also, Creco and Blake (1983) reported that intraspecific competition for food may be more importent than interspecific competition for coexisting larvae of American shad and blueback herring in the Connecticut River. On the Pamunkey the top two species were blueback herring and spottail shiners and according to Wells (1980) they do not compete for food either.

Both river communities do not appear to change with time and are considered to be persistent. The top ten species from each river were significantly correlated and considered to be deterministically derived. Moyle and Vondrack (1985) and Matthews (1986) found similar results in the communities they studied.

The low fidelity indices for the temporal clusters for both rivers also point to deterministic communities. If the species groups were limited and thus showed high fidelity to certain year groups that would indicate a stochastic community. Fidelity for all temporal clusters were low, except for species group G on the Mattaponi, species group I on the Pamunkey and species groups C, E, and F in the combined cluster. The species which made up those groups were rare and the high fidelity may be artificial.

The lack of competition for food for the top two abundant species on each river points to partitioning of diet by the species in the community. Partioning of diet is another characteristic of a deterministic community.

Diversity for both rivers varied from year to year which would suggest stochastic communities but based on the evidence listed above they were still considered to be deterministic communities. The wide variation in diversity appears to be a result of variation in year class strength of the dominant species rather than changes in absolute community compostion, with resultant fluctuations in evenness thus affecting diversity.

Richness, and evenness were higher on the Mattaponi than on the Pamunkey. More species were found on the Mattaponi which increased richness. The large number of bluebacks in the Pamunkey decreased evenness.

SPATIAL

There was no evidence of zonation or downstream addition of species. As mentioned above Rahel and Hurbert (1991) found that longitudinal succession depended on spatial scales. They found that on large spatial scales the zone hypothsis was true and that within the zones the addition hypothesis was true. Thus, the spatial scales may not have been large enough to find evidence of distinct fish zones. Also, the strata sampled were basically uniform in environmental compostion. Variability in the addition of species as one proceeds downstream was found (Table 6 and 9). The addition of species may have been affected by the tidal movements. The studies which found species additions going downstream were all conducted in nontidal freshwater systems (Sheldon 1986; Jenkins and Freeman 1972; Evans and Noble 1979). Juvenile fishes move up and downstream with the tide. The sampling was done at different tidal stages and since the tide stage was not taken into account, and how the species were distributed with each tide stage was not known.

It appears that spatially the species groups change from year to year on the Mattaponi since the groups are not found clustered near each other most of the years (Fig. 14). On the Pamunkey the spatial species groups appear to be more stable (Fig. 16).

The results from the logistic regression model were inconclusive. The model fit some of the years for all the species tested except for the Atlantic menhaden which had a saturated model every year (Table 9). The model may have only fit for some of the years because other factors or a combination of other factors had a greater affect on the species distribution than strata volume. Other factors affecting the species distribution besides strata volume could be river flow, salinity, dissolved oxygen, water temperature, water depth, distribution of prey, and distribution of predators.

Another reason the model may have only fit for some years is, as mentioned above, that the sampling was done at different tidal stages. The volume of the strata and the concentration of the fish changes with tide stage if the fish are activly swimming. At high tide the fish concentration is pushed upstream, the volume of the strata is increased, and the fish can spread out since there is more water (they can also go into the marsh areas). Therefore at times of high tide less fish would be caught in the net because they would be spread out and not concentrated in the channel. At low tide the fish concentration move further downstream, the strata volume is decreased, the fish are concentrated in the channel, and the pushnet will catch more. Tide stage was not recorded for each station so some years most of the collections may have been done at one particular tide stage while other years data may have been collected at a different tide stage which would increase the variability in the data.

CONCLUSION

The Mattaponi and the Pamunkey have similar species. However, the community structures are different for each river. This could be due to environmental differences between the two rivers.

Both river communities are persistent from year to year. Diversity does vary from year to year for both rivers which would suggest a stochastic community; however, the Kendall's rank test, diet partitioning, and the fidelity indices indicated that both communities were deterministic.

There did not appear to be a downstream addition of species nor distinct fish zones. The study area may have been too small to produce distinct fish zones or to detect a downstream addition of species. Tidal effects not taken into account in the sampling scheme also could have effected these results.

When strata volume affected CPUE, as strata volume increased CPUE decreased for all species except for blueback herring in 1986 and spottail shiner in 1983 on the Pamunkey.

Table 1. A list of the species found in the Mattaponi and Pamunkey rivers.

Scientific name	Common name	MP	PM
Alosa aestivalis	blueback	X	X
Alosa mediocris	hickory shad	X	X
Alosa pseudoharengus	alewife	X	X
Alosa sapidissima	american shad	X	X
Anchoa mitchilli	bay anchovy	X	X
Anguilla rostrata	American eel	X	X
Brevoortia tyrannus	Atlantic menhaden	X	X
Enneacanthus gloriosus	bluespotted sunfish	X	
Enneacanthus obesus	banded sunfish	X	
Esox niger	chain pickerel	X	X
Etheostoma olmstedi	tessellated darter	X	X
Fundulus diaphanus	banded killifish	X	X
Hybognathus regius	Eastern silvery min.	X	X
Ictalurus catus	white catfish	X	X
Ictalurus melas	black bullhead cat.	X	
Ictalurus nebulosus	brown bullhead cat.	X	
Ictalurus punctatus	channel catfish	X	X
Leiostomus xanthurus	spot		X
Lepisosteus osseus	longnose gar	X	
Lepomis auritus	redbreast sunfish	X	
Lepomis cyanellus	green sunfish	X	X
Lepomis gibbosus	pumpkinseed	X	X
Lepomis macrochirus	bluegill	X	X
Membras martinica	rough silverside	X	
Menidia beryllina	inland silverside	X	X
Micropterus dolomieui	smallmouth bass	X	X
Micropterus salmoides	largemouth bass	X	X
Morone americana	white perch	X	X
Morone saxatilis	striped bass	X	X
Notemigonus crysoleucas	golden shiner	X	X
Notropis analostanus	satinfin shiner	X	X
Notropis bifrenatus	bridle shiner		X
Notropis hudsonius	spottail shiner	X	X
Perca flavescens	yellow perch	X	
Pomoxis nigromaculatus	black crappie	X	
Strongylura marina	Atlantic needlefish	X	X
Trinectes maculatus	hogchoker	X	X

Table 2. Species diversity (S, H', N_1, λ, N_2), evenness (E), richness (R), and total CPUE for each year for both the Mattaponi and the Pamunkey Rivers. Forty five tows were taken each summer on the Mattaponi. Forty eight tows were done on the Pamunkey.

YEAR MATTAPONI	S	TOTAL CPUE	H'	N_1	λ	N_2	R	E
1983	22	49.01	1.77	5.87	.209	4.78	5.40	.776
1984	21	318.24	1.16	3.19	.451	2.22	3.47	.557
1985	24	176.07	.83	2.29	.627	1.59	4.45	.457
1986	20	43.09	1.75	5.75	.223	4.48	5.05	.733
1987	18	34.98	2.06	7.85	.147	6.80	4.78	.847
1991	17	23.56	1.92	6.82	.153	6.54	5.06	.952
PAMUNKEY								
1983	19	151.09	.95	2.59	.618	1.62	3.59	.390
1984	19	82.29	1.18	3.25	.511	1.96	4.08	.427
1985	16	190.35	.98	2.66	.569	1.76	2.86	.458
1986	19	130.01	1.66	5.26	.296	3.38	3.70	.559
1987	16	181.09	.60	1.82	.777	1.29	2.89	.354
1991	17	37.43	1.95	7.03	.162	6.17	4.42	.857

Table 3. The ten most abundant species found in the Mattaponi and the Pamunkey rivers from 1983-1987.

	MP	PM
Alosa aestivalis blueback	1	1
Alosa sapidissima American shad	2	5
Hybognathus regius Eastern silvery minnow	3	4
Notropis hudsonius spottail shiner	7	2
Alosa pseudoharengus alewife	4	6
Ictalurus catus white catfish	5	10
Morone americana white perch	6	8
Anchoa mitchilli bay anchoy	9	7
Brevoortia tyrannus Atlantic menhaden	13	3
Ictalurus punctatus channel catfish	8	11
Menidia beryllina inland silverside	10	9

Table 4. The rankings of the ten most abundant species found in A) the Mattaponi and B) Pamunkey rivers from 1983-1987.

A. Rankings for the species on the Mattaponi	83	84	85	86	87
Alosa aestivalis blueback	2	1	1	2	6
Alosa pseudoharengus alewife	5	4	3	4	8
Alosa sapidissima American shad	1	3	2	1	1
Anchoa mitchilli bay anchoy	10	8	6	5	10
Hybognathus regius Eastern silvery min.	4	2	7	10	7
Ictalurus catus white catfish	6	5	4	7	4
Ictalurus punctatus channel catfish	9	9.5	8	6	3
Menidia beryllina inland silverside	8	9.5	9	8	9
Morone americana white perch	3	7	10	9	2
Notropis hudsonius spottail shiner	7	6	5	3	5

B. Rankings for the species on the Pamunkey.	83	84	85	86	87
Alosa aestivalis blueback	1	1	1	1	1
Alosa pseudoharengus alewife	7	9	4	4	8
Alosa sapidissima American shad	3	7	3	5	9
Anchoa mitchilli bay anchoy	0	4	6.5	7	4
Brevoortia tyrannus Atlantic menhaden	5	2	2	3	10
Hybognathus regius Eastern silvery min.	2	3	5	6	2
Ictalurus catus white catfish	9	10	9	10	6
Menidia beryllina inland silverside	8	8	10	9	5
Morone americana white perch	4	6	8	8	7
Notropis hudsonius spottail shiner	6	5	6.5	2	3

Table 5. Results of the Kendall's rank test for the Mattaponi and the Pamunkey rivers for the years 1983-1987.

River	No. of Yrs	S	W	P
Mattaponi	5	10	.538	P<.01
Pamunkey	5	10	.557	P<.01

Table 6. Species diversity (S, H', N_1, λ, N_2), evenness (E), richness (R), and total CPUE for each strata for both the Mattaponi and the Pamunkey rivers sampling years A) 1983, B) 1984, C) 1985, D) 1986, E) 1987, and F) 1991. Fifteen tows were taken each summer for each strata on the Mattaponi. Twelve tows were done per strata on the Pamunkey.

YEAR	A. 1983							
MATTTAPONI	S	CPUE	H'	N_1	λ	N_2	R	E
59-55	14	35.29	1.45	4.26	.281	3.56	3.65	.785
54-50	17	59.54	1.69	5.42	.244	4.10	3.92	.701
49-45	13	52.27	1.60	4.95	.249	4.02	3.03	.765
PAMUNKEY								
69-65	14	18.39	1.51	4.53	.306	3.27	4.46	.643
64-60	9	47.84	1.18	3.25	.430	2.33	2.07	.591
59-55	13	78.83	1.29	3.63	.402	2.49	2.75	.567
54-50	14	459.33	.67	1.95	.733	1.36	2.12	.379

	B. 1984							
MATTAPONI	S	CPUE	H'	N_1	λ	N_2	R	E
59-55	18	302.61	1.06	2.89	.477	2.10	2.98	.582
54-50	15	332.67	1.29	3.63	.363	2.75	2.41	.665
49-45	11	319.54	.87	2.39	.603	1.66	1.73	.475
PAMUNKEY								
69-65	9	11.81	1.37	3.94	.259	3.86	3.24	.973
64-60	10	39.58	.92	2.51	.577	1.73	2.45	.483
59-55	13	71.64	1.14	3.13	.461	2.17	2.81	.549
54-50	15	206.17	1.01	2.75	.557	1.80	2.63	.457

	C. 1985							
MATTAPONI	S	CPUE	H'	N_1	λ	N_2	R	E
59-55	18	121.47	.81	2.25	.604	1.66	3.54	.528
54-50	17	193.07	.69	1.99	.693	1.44	3.04	.444
49-45	15	213.68	.88	2.41	.589	1.70	2.61	.496
PAMUNKEY								
69-65	10	35.33	1.38	3.97	.320	3.13	2.52	.717
64-60	10	53.93	1.28	3.60	.388	2.58	2.26	.608
59-55	11	189.07	.64	1.90	.742	1.35	1.91	.389
54-50	13	483.01	.81	2.25	.601	1.66	1.94	.528

D. 1986

MATTAPONI	S	CPUE	H'	N_1	λ	N_2	R	E
59-55	12	70.07	1.42	4.14	.284	3.52	2.59	.803
54-50	15	25.35	1.55	4.71	.264	3.79	4.33	.752
49-45	15	33.95	1.90	6.69	.188	5.32	3.97	.759
PAMUNKEY								
69-65	12	44.75	1.58	4.85	.246	4.07	2.89	.797
64-60	12	70.82	1.60	4.95	.254	3.94	2.58	.744
59-55	15	204.81	1.58	4.85	.309	3.24	2.63	.582
54-50	12	195.74	1.20	3.32	.388	2.58	2.08	.681

E. 1987

MATTAPONI	S	CPUE	H'	N_1	λ	N_2	R	E
59-55	16	38.80	1.67	5.31	.294	3.40	4.10	.557
54-50	15	45.73	2.10	8.17	.125	8.00	3.66	.976
49-45	12	20.41	1.59	4.90	.291	3.44	3.65	.626
PAMUNKEY								
69-65	13	58.34	.78	2.18	.667	1.50	2.95	.424
64-60	10	155.08	.38	1.46	.842	1.19	1.78	.413
59-55	11	151.75	.49	1.63	.811	1.23	1.99	.365
54-50	14	359.17	.64	1.90	.756	1.32	2.21	.356

F. 1991

MATTAPONI	S	CPUE	H'	N_1	λ	N_2	R	E
59-55	11	27.75	1.50	4.48	.238	4.20	3.01	.920
54-50	14	15.53	1.80	6.05	.170	5.88	4.74	.966
49-45	14	27.46	1.56	4.76	.341	2.93	3.92	.513
PAMUNKEY								
69-65	10	16.48	1.38	3.97	.268	3.73	3.21	.919
64-60	13	49.91	1.55	4.71	.264	3.79	3.07	.752
59-55	13	36.82	1.93	6.89	.167	5.99	3.33	.847
54-50	12	46.48	1.69	5.42	.224	4.46	2.87	.783

Table 7. A definition of each strata and the volume of each strata at mean low water.*

RIVER	STRATA	RIVER MILES	VOLUME**	VELOCITY***
MATTAPONI	I	59-55	10.01	3.21
	II	54-50	20.01	1.61
	III	49-45	25.03	1.28
PAMUNKEY	I	69-65	5.01	11.96
	II	64-60	10.84	5.53
	III	59-55	24.74	2.42
	IV	54-50	31.98	1.87

*Volumes were calculated using information from Cronin (1971).
**Volumes were x 10^5 m^3.
***Velocities were x 10^{-5} km/s.

Table 8. Summary of logistic regression model fitting.

	Model fit Null hypothesis rejected	Model fit Null hypothesis not rejected	Model doesn't fit
MATTAPONI			
BB	1986,1987,1991	1984	1983,1985
AS	1983,1984,1987		1985,1986,1991
ESM	1983,1991	1984	1985,1986,1987
PAMUNKEY			
BB	1986	1985	1983,1984,1987,1991
SS	1983,1984,1985,1991	1986	1987
MH*			

* For all the years the model was saturated.

Table 9. A list of the species found each strata.

	Mattaponi			Pamunkey			
Strata	I	II	III	I	II	III	IV
Common name	59-55	54-50	49-45	69-65	64-60	59-55	54-50
alewife	X	X	X	X	X	X	X
American shad	X	X	X	X	X	X	X
Atlantic needle.	X	X	X	X	X	X	X
bay anchovy	X	X	X	X	X	X	X
blueback	X	X	X	X	X	X	X
channel catfish	X	X	X	X	X	X	X
Eastern silv. min.	X	X	X	X	X	X	X
hogchoker	X	X	X	X	X	X	X
inland silverside	X	X	X	X	X	X	X
spottail shiner	X	X	X	X	X	X	X
striped bass	X	X	X	X	X	X	X
white catfish	X	X	X	X	X	X	X
white perch	X	X	X	X	X	X	X
tessellated dart.	X	X	X	X	X	X	
Atlantic menhaden	X		X		X	X	X
banded killifish	X	X	X				X
bluegill	X	X	X				X
hickory shad	X	X	X				X
satinfin shiner	X			X	X	X	
brown bull. cat.	X	X	X				
golden shiner	X			X	X		
redbreast sunfish	X	X	X				
American eel	X			X			
banded sunfish	X	X					
black crappie	X	X					
chain pickerel	X				X		
green sunfish		X				X	
largemouth bass	X			X			
pumpkinseed		X		X			
rough silverside		X	X				
smallmouth bass		X		X			
black bull. cat.	X						
bluespotted sun.		X					
bridle shiner				X			
longnose gar	X						
spot							X
yellow perch	X						
Number of species	30	26	21	21	18	17	18

Figure 1. Chart locating the study areas on the Mattaponi and the Pamunkey rivers.

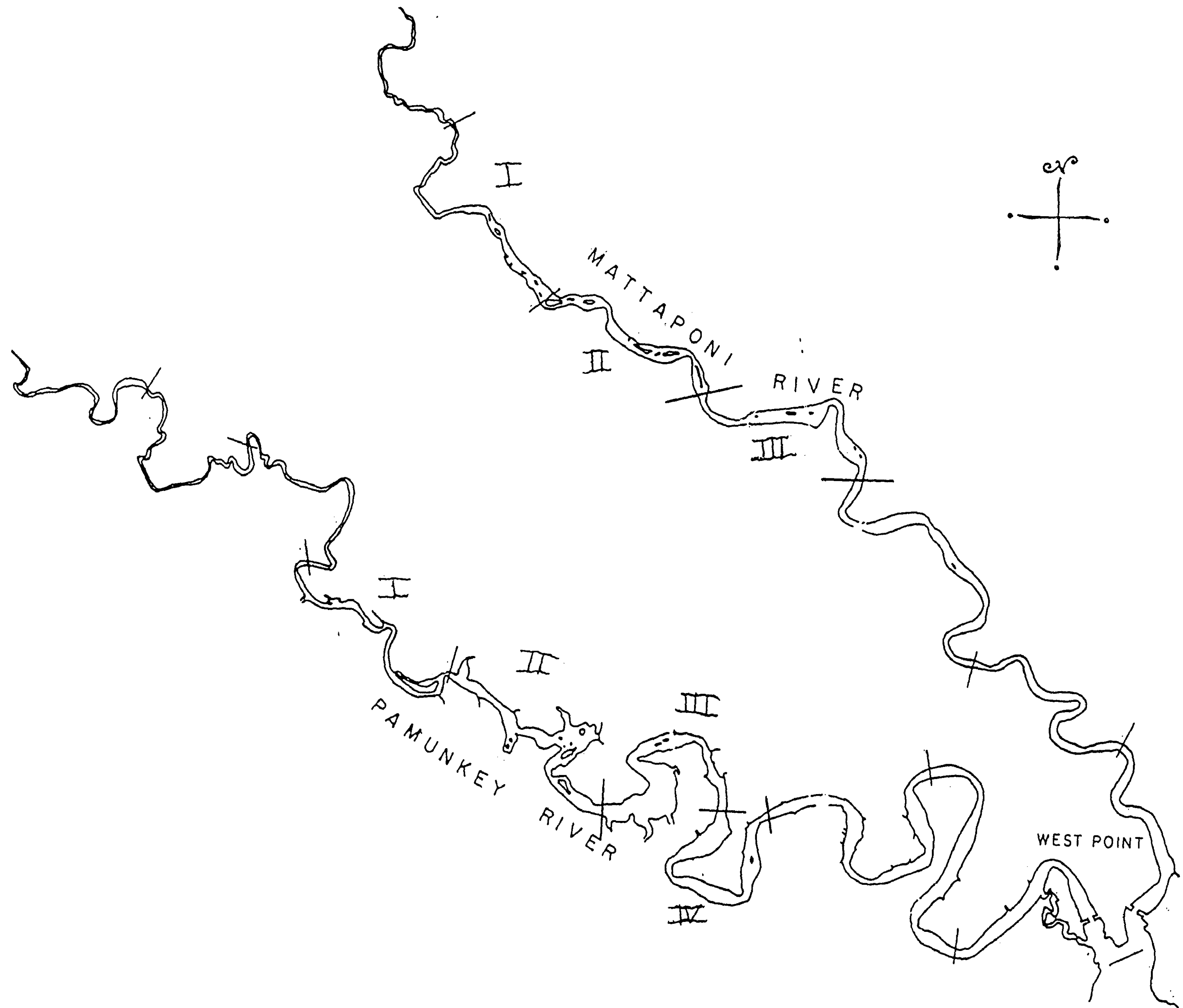
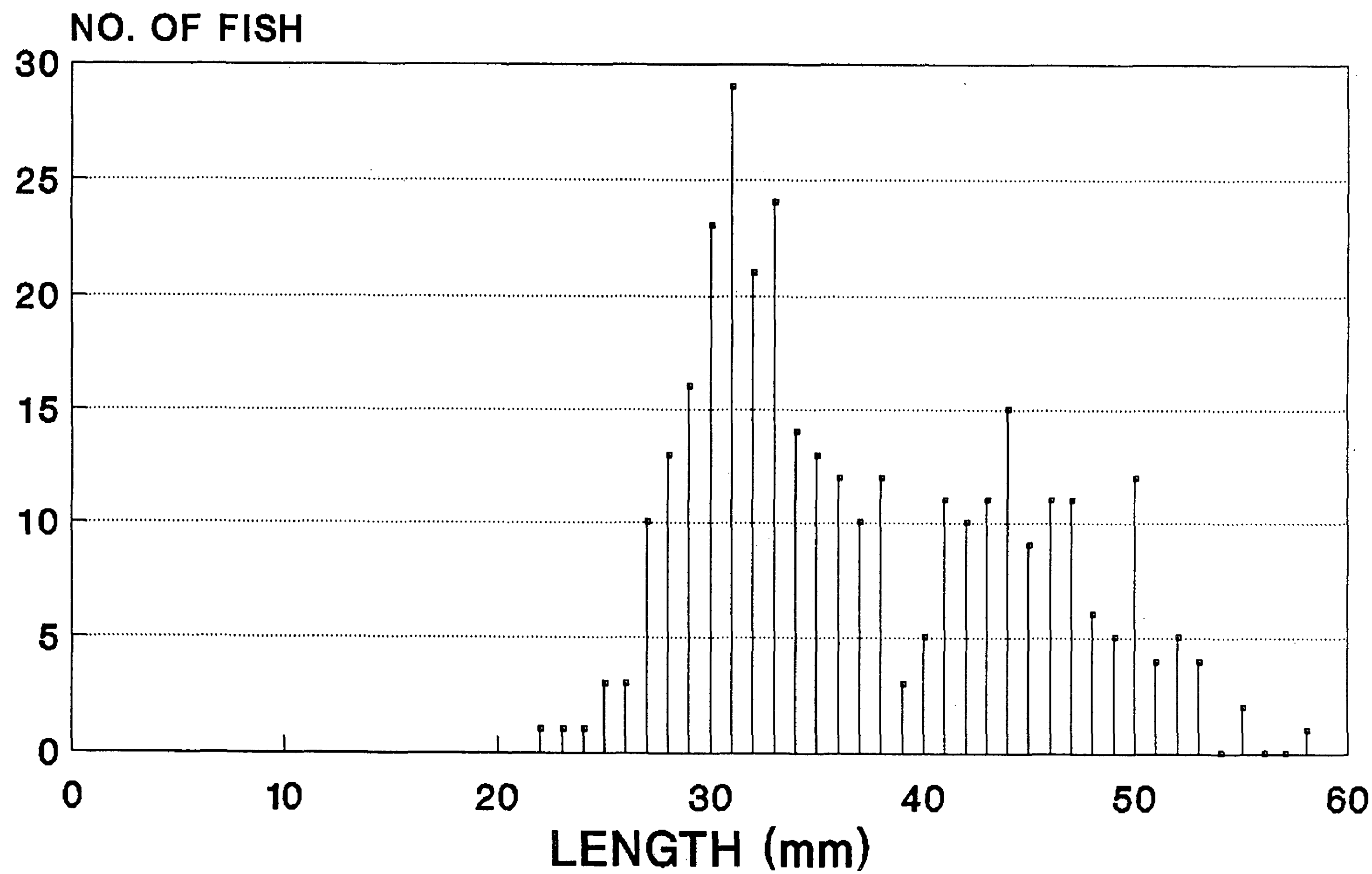
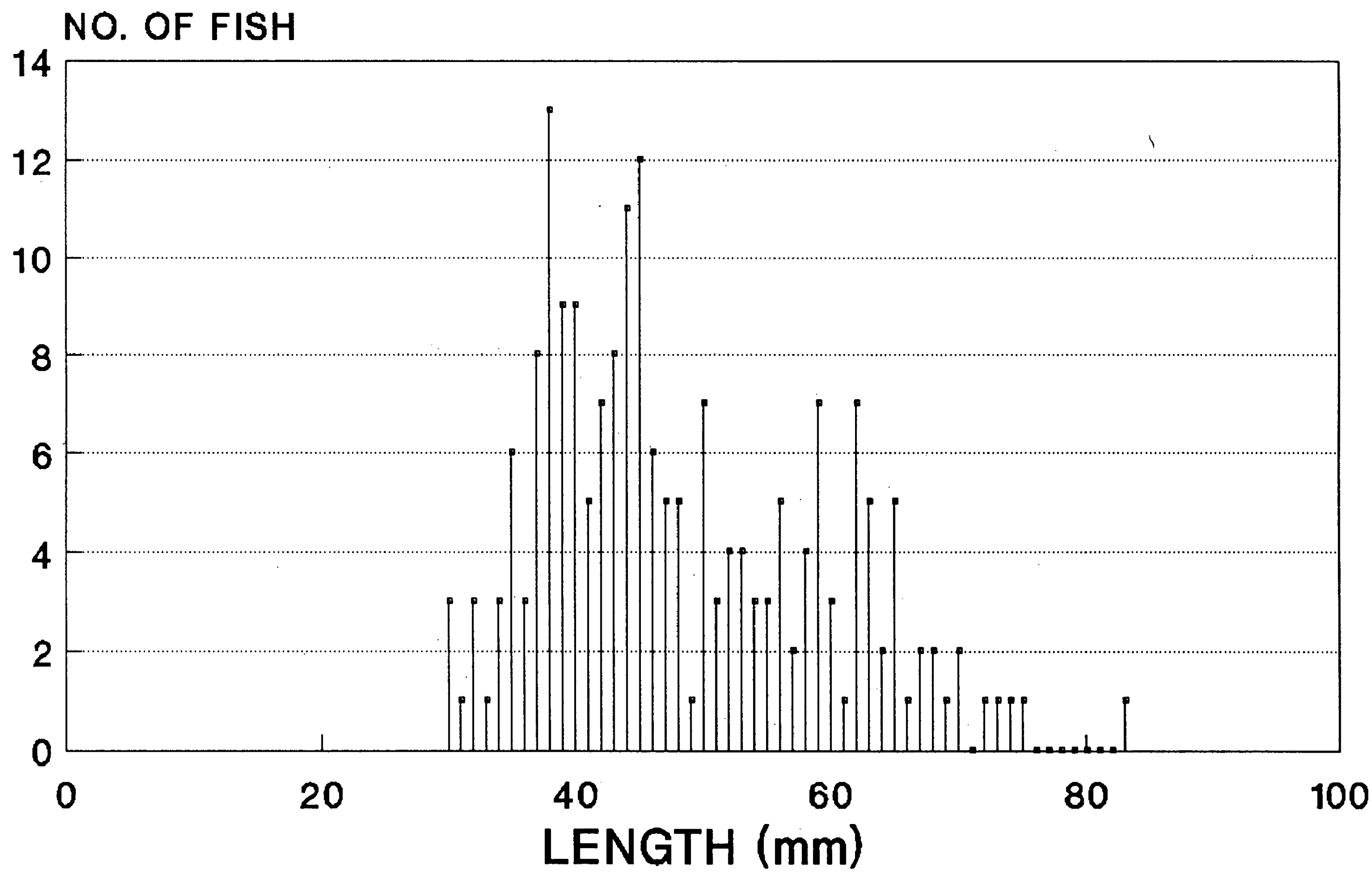

MATTAPONI RIVER
PAMUNKEY RIVER
WEST POINT
I
II
III
I
II
III
IV

Figure 2(a-c). Length frequency distribution for the three most abundant species found in the Mattaponi a) blueback b) American shad and c) Eastern silvery minnow.

MATTAPONI
bluebacks



MATTAPONI
American shad



MATTAPONI

Eastern silvery minnow

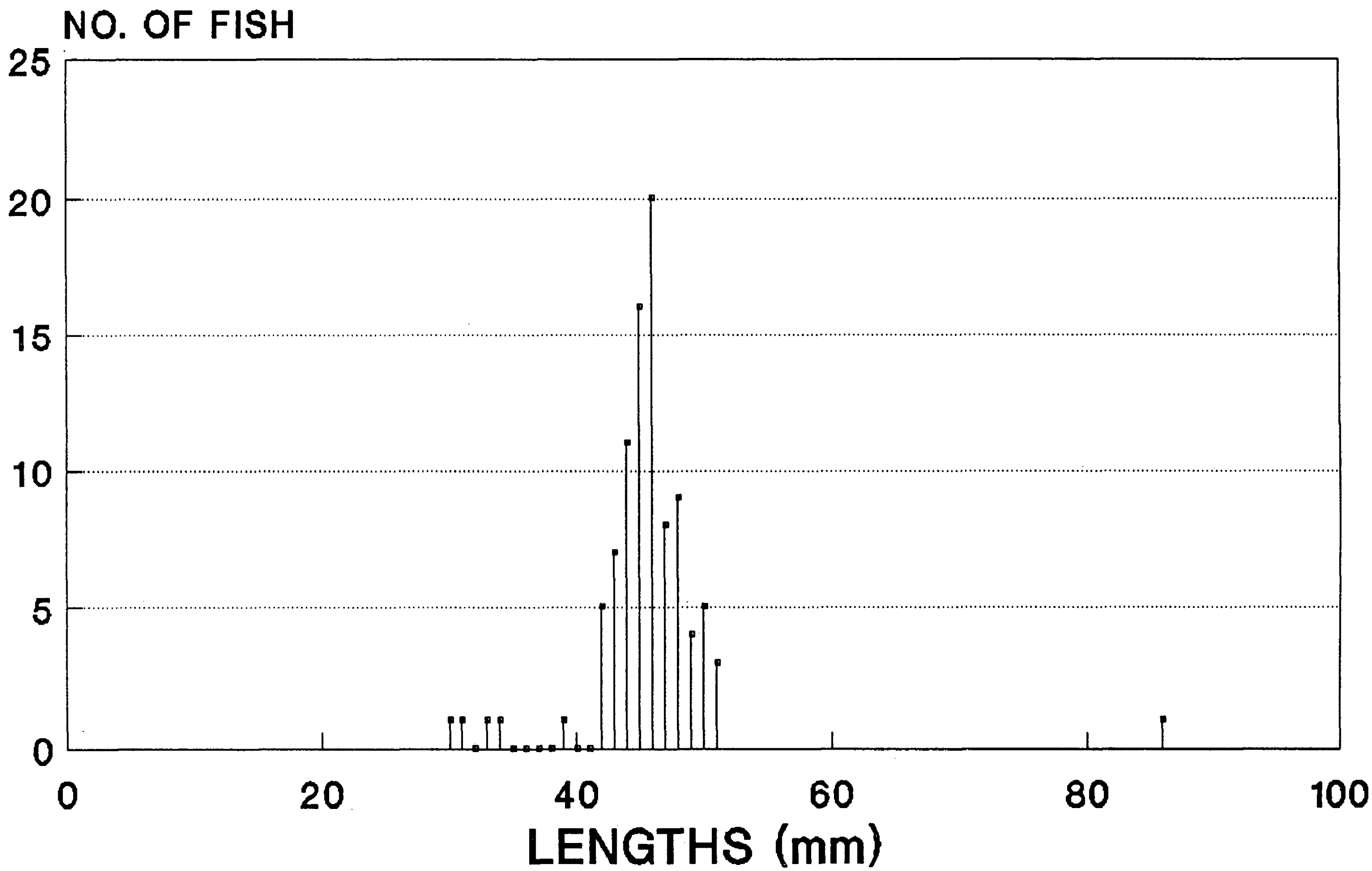
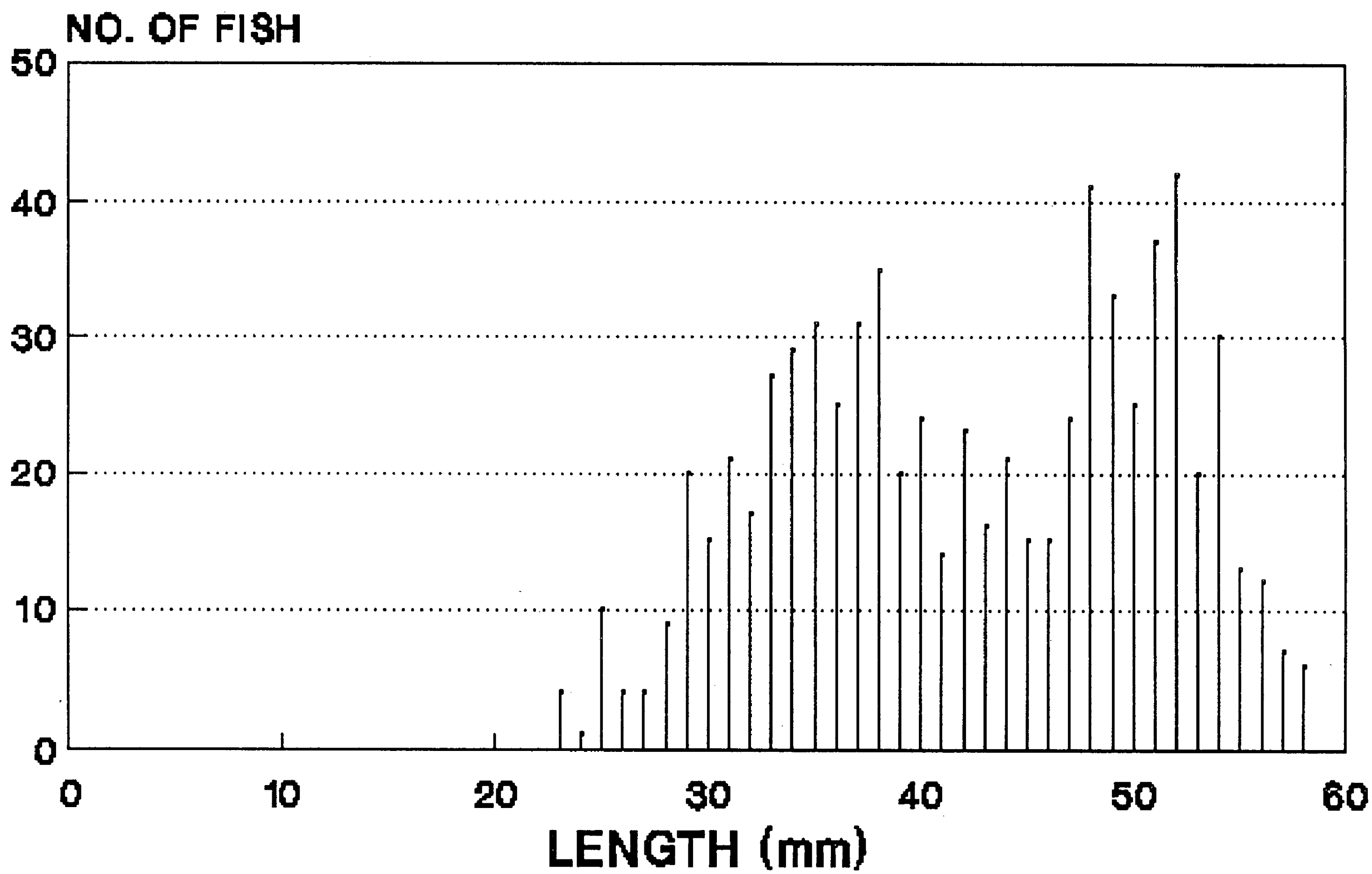
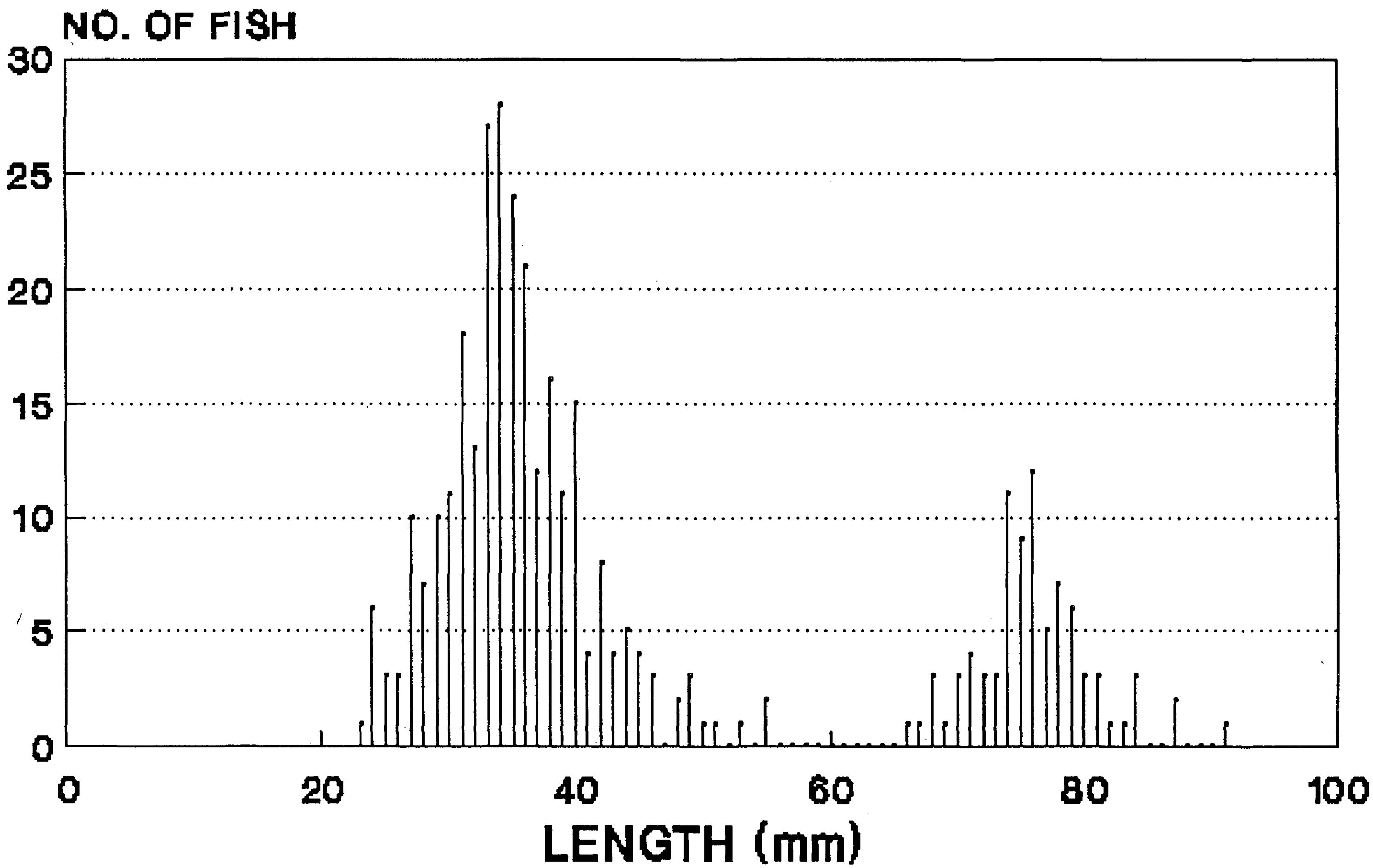


Figure 3(a-c). Length frequency for the three most abundant species found in the Pamunkey a) blueback, b) spottail shiner, and c) Atlantic menhaden.

PAMUNKEY
bluebacks



PAMUNKEY
spottail shiner



PAMUNKEY
Atlantic menhaden

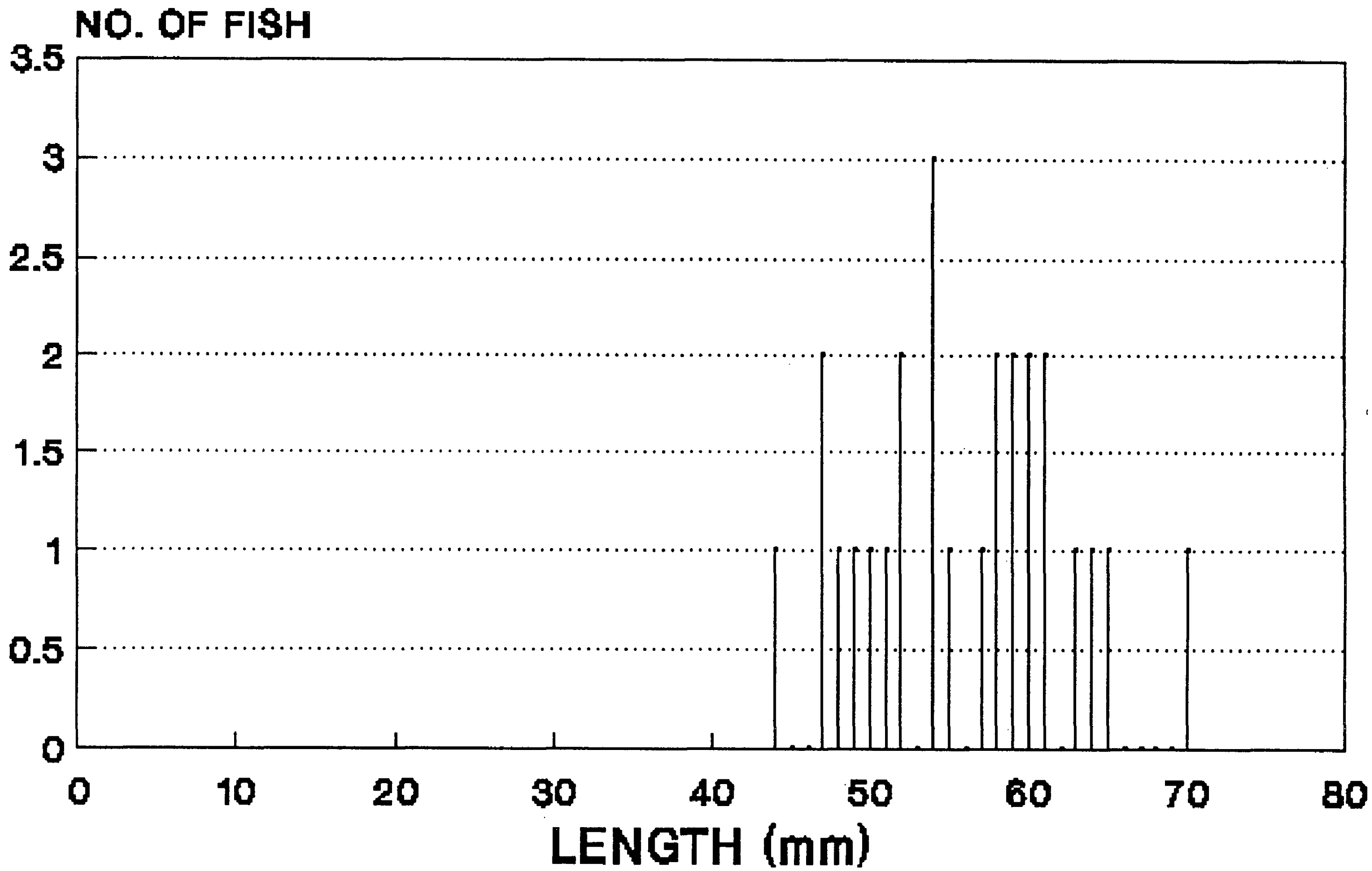
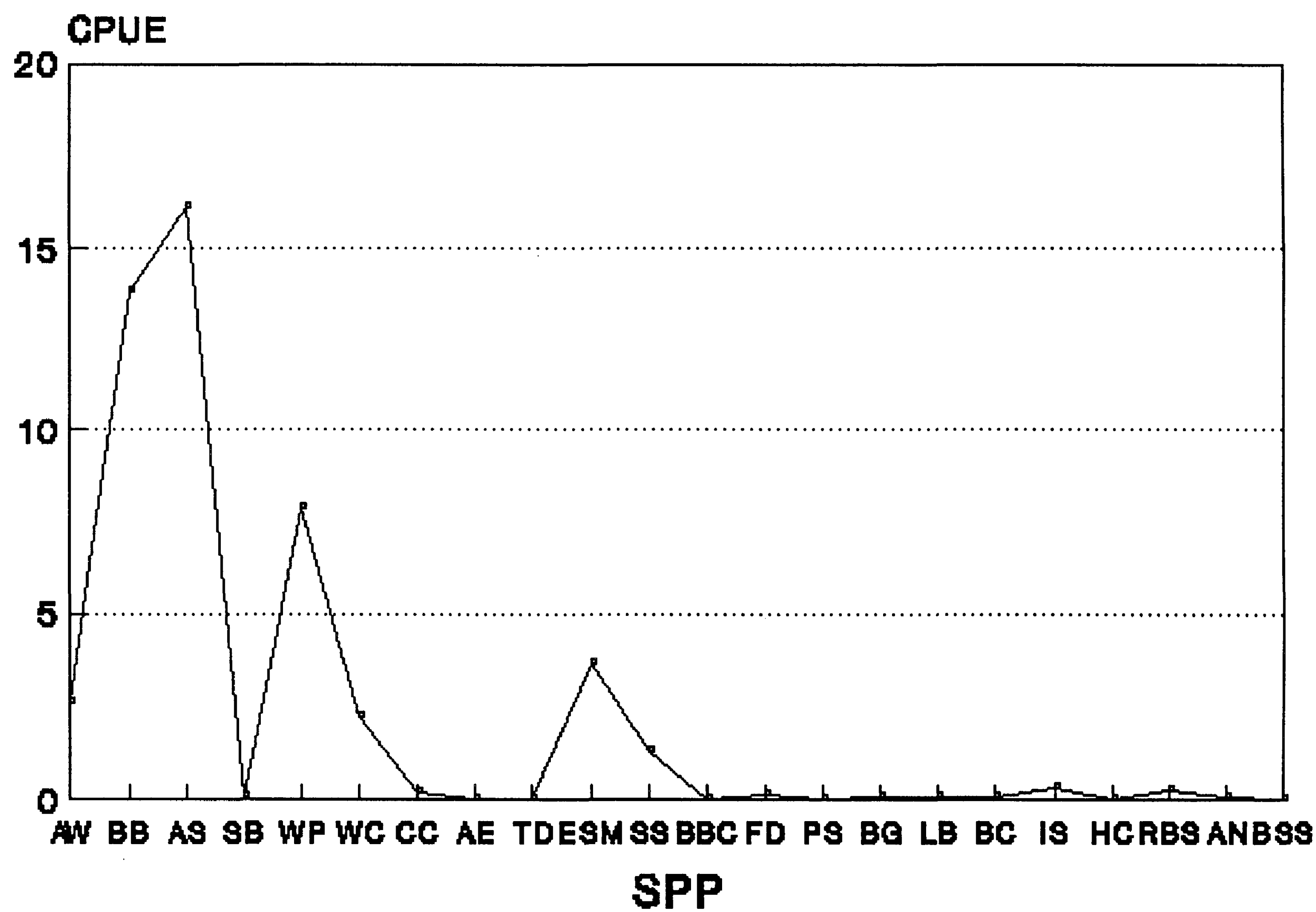


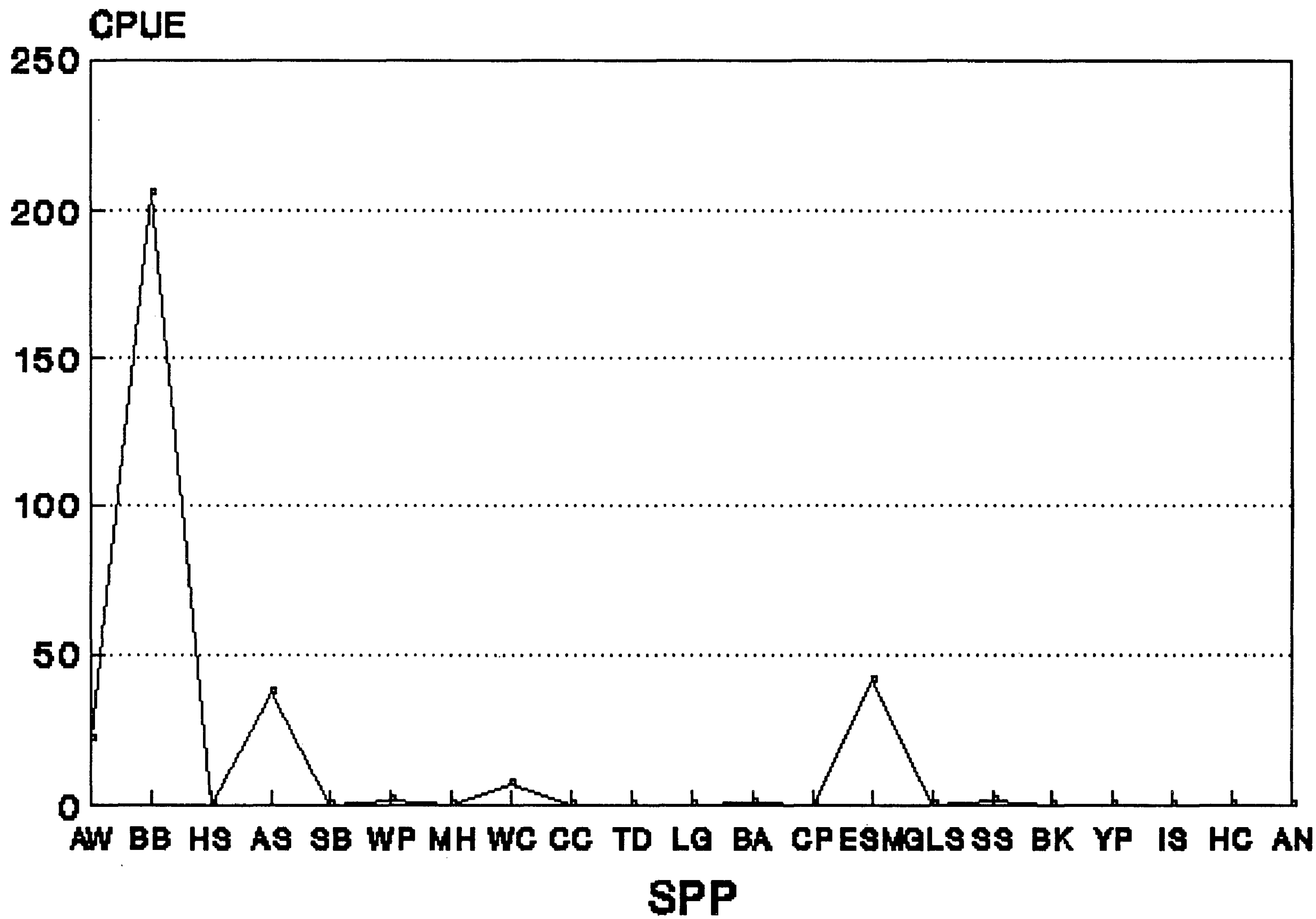
Figure 4(a-f). The catch per unit effort (CPUE) of each species on the Mattaponi for the years a) 1983, b) 1984, c) 1985, d) 1986, e) 1987, and f) 1991. Species abbreviations are:

AE	American eel
AM	Atlantic menhaden
AN	Atlantic needlefish
AS	American shad
AW	alewife
BA	bay anchovy
BB	blueback
BBC	brown bullhead cat.
BC	black crappie
BDS	bridle shiner
BG	bluegill
BK	banded killifish
BLBC	black bullhead cat.
BS	banded sunfish
BSS	bluespotted sunfish
CC	channel catfish
CP	chain pickerel
ESM	Eastern silvery min.
GLS	golden shiner
GS	green sunfish
HG	hogchoker
HS	hickory shad
IS	inland silverside
LB	largemouth bass
LG	longnose gar
PS	pumpkinseed
RBS	redbreast sunfish
RS	rough silverside
S	spot
SB	striped bass
SFS	satinfin shiner
SMB	smallmouth bass
SS	spottail shiner
TD	tessellated darter
WC	white catfish
WP	white perch
YP	yellow perch

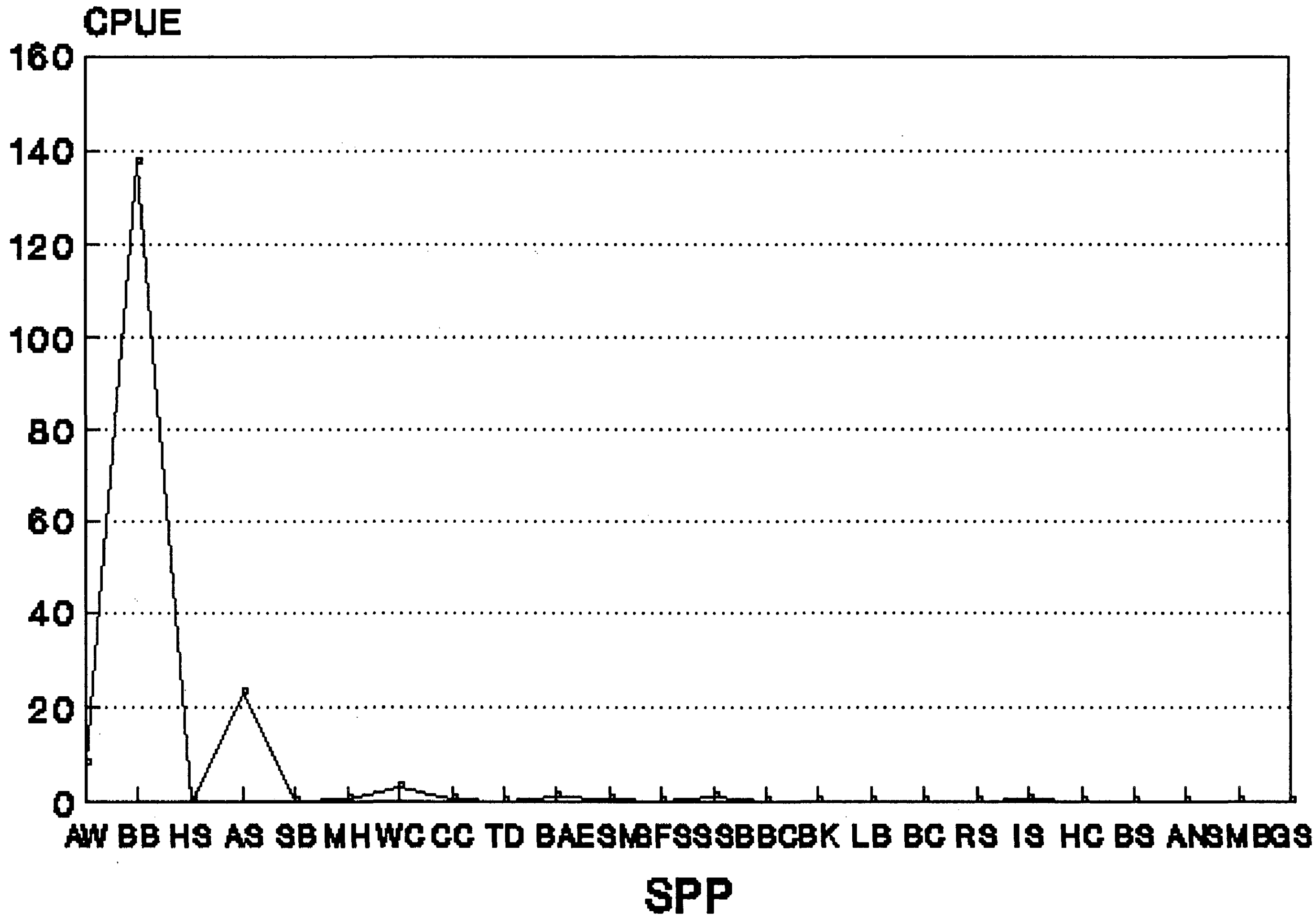
A MATTAPONI 1983



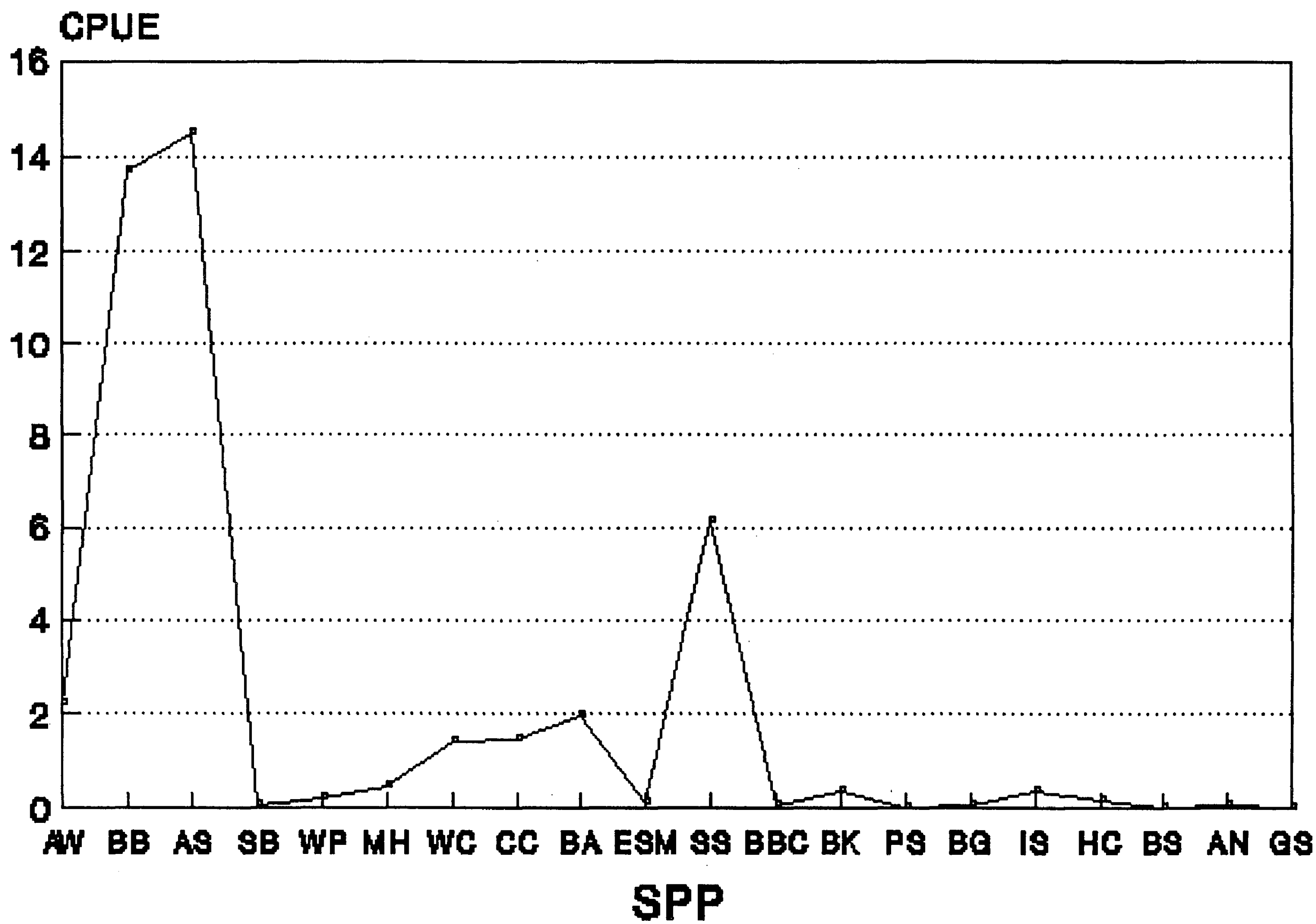
B MATTAPONI 1984



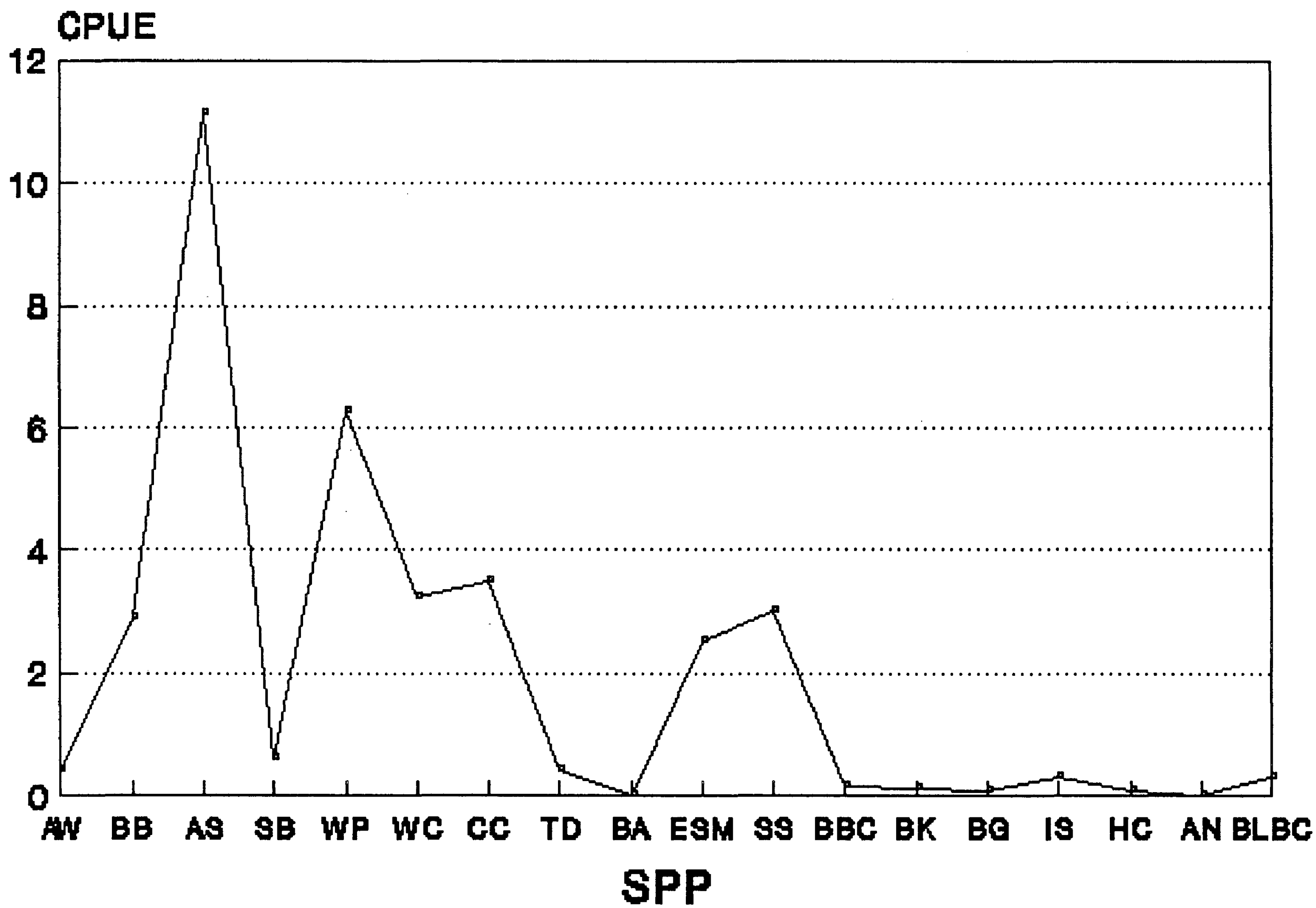
C MATTAPONI 1985



D MATTAPONI 1986



E MATTAPONI 1987



F MATTAPONI 1991

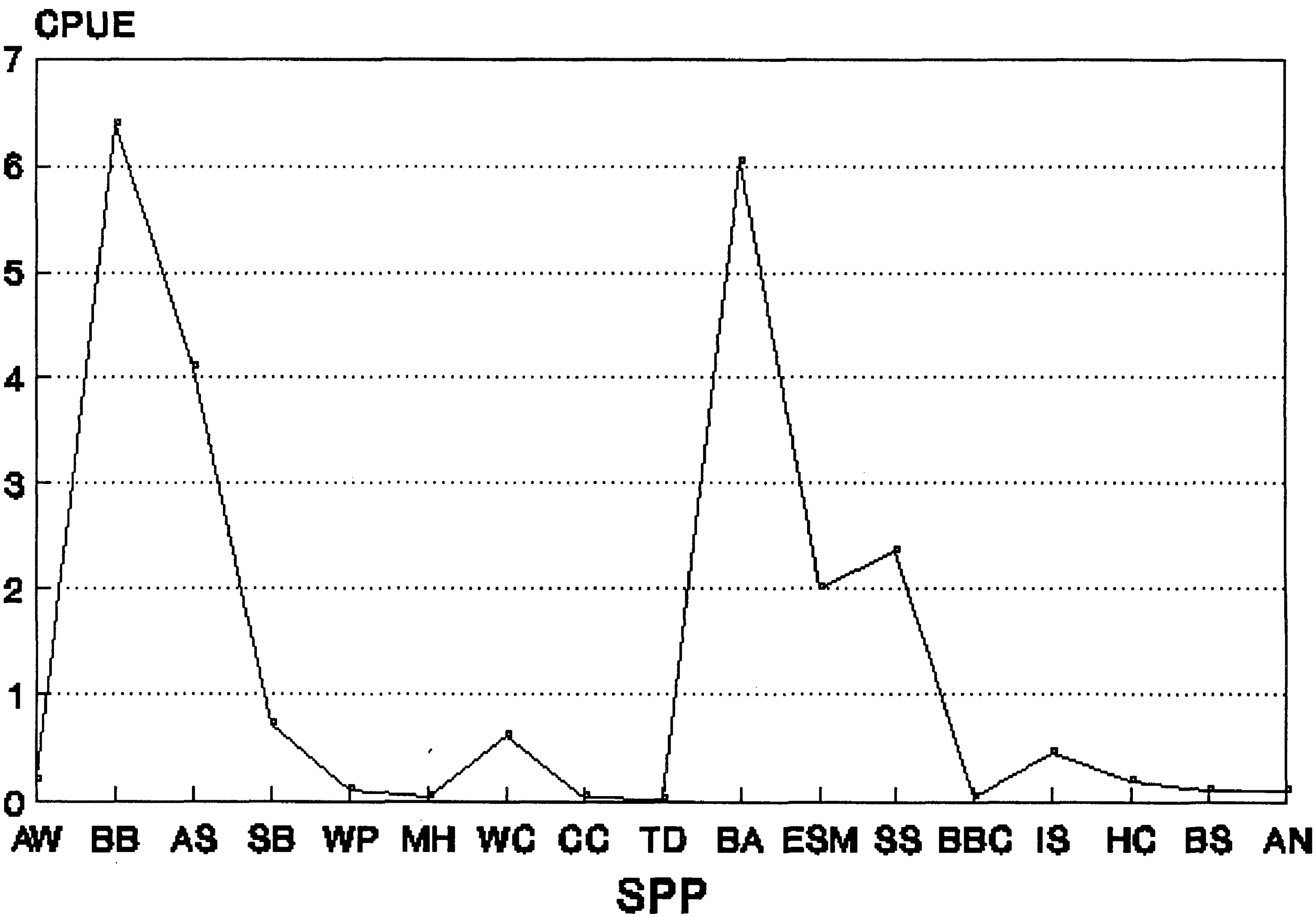
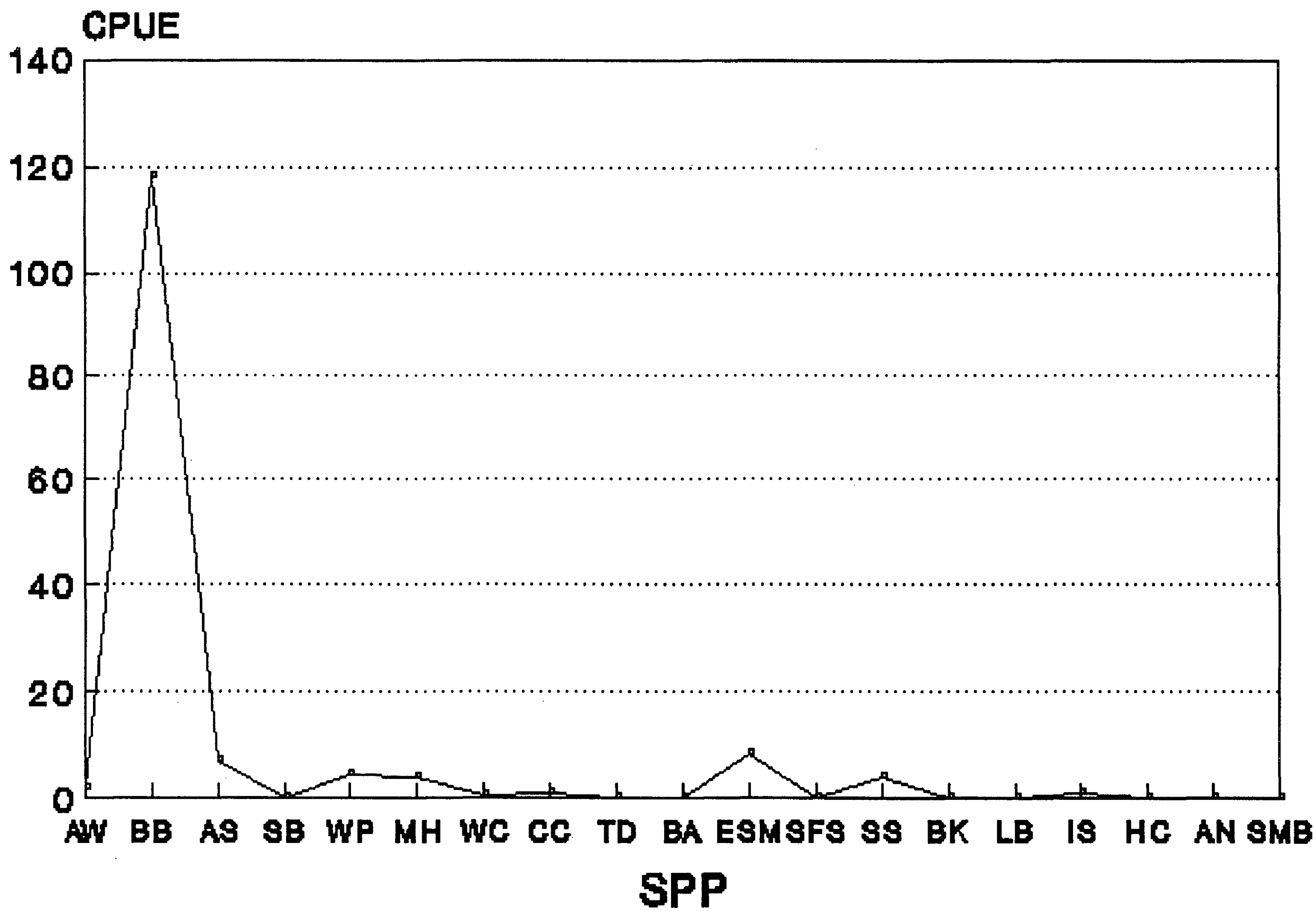


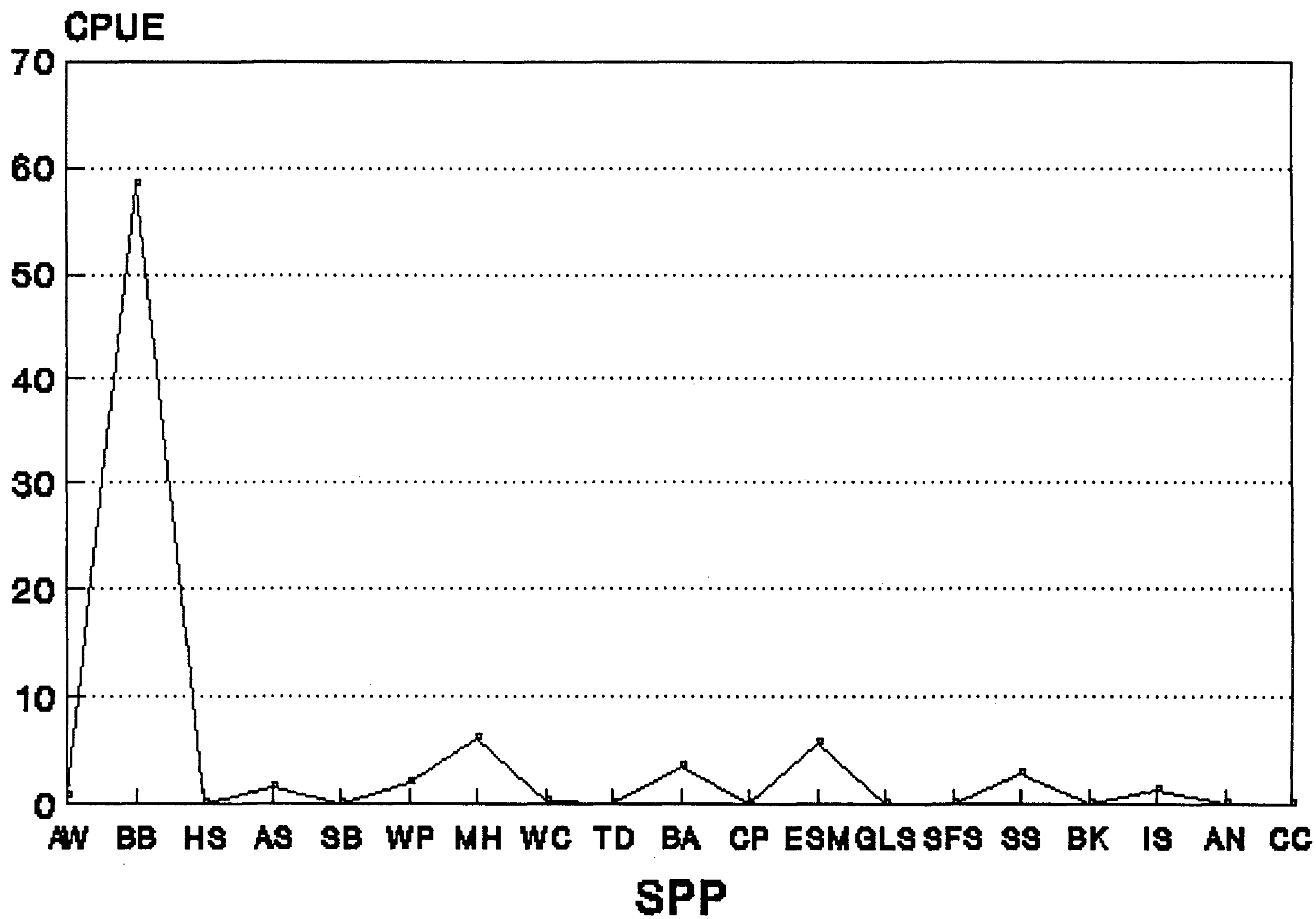
Figure 5(a-f). The catch per unit effort (CPUE) of each species on the Pamunkey for the years a) 1983, b) 1984, c) 1985, d) 1986, e) 1987, and f) 1991.

AE	American eel
AM	Atlantic menhaden
AN	Atlantic needlefish
AS	American shad
AW	alewife
BA	bay anchovy
BB	blueback
BBC	brown bullhead cat.
BC	black crappie
BDS	bridle shiner
BG	bluegill
BK	banded killifish
BLBC	black bullhead cat.
BS	banded sunfish
BSS	bluespotted sunfish
CC	channel catfish
CP	chain pickerel
ESM	Eastern silvery min.
GLS	golden shiner
GS	green sunfish
HG	hogchoker
HS	hickory shad
IS	inland silverside
LB	largemouth bass
LG	longnose gar
PS	pumpkinseed
RBS	redbreast sunfish
RS	rough silverside
S	spot
SB	striped bass
SFS	satinfin shiner
SMB	smallmouth bass
SS	spottail shiner
TD	tessellated darter
WC	white catfish
WP	white perch
YP	yellow perch

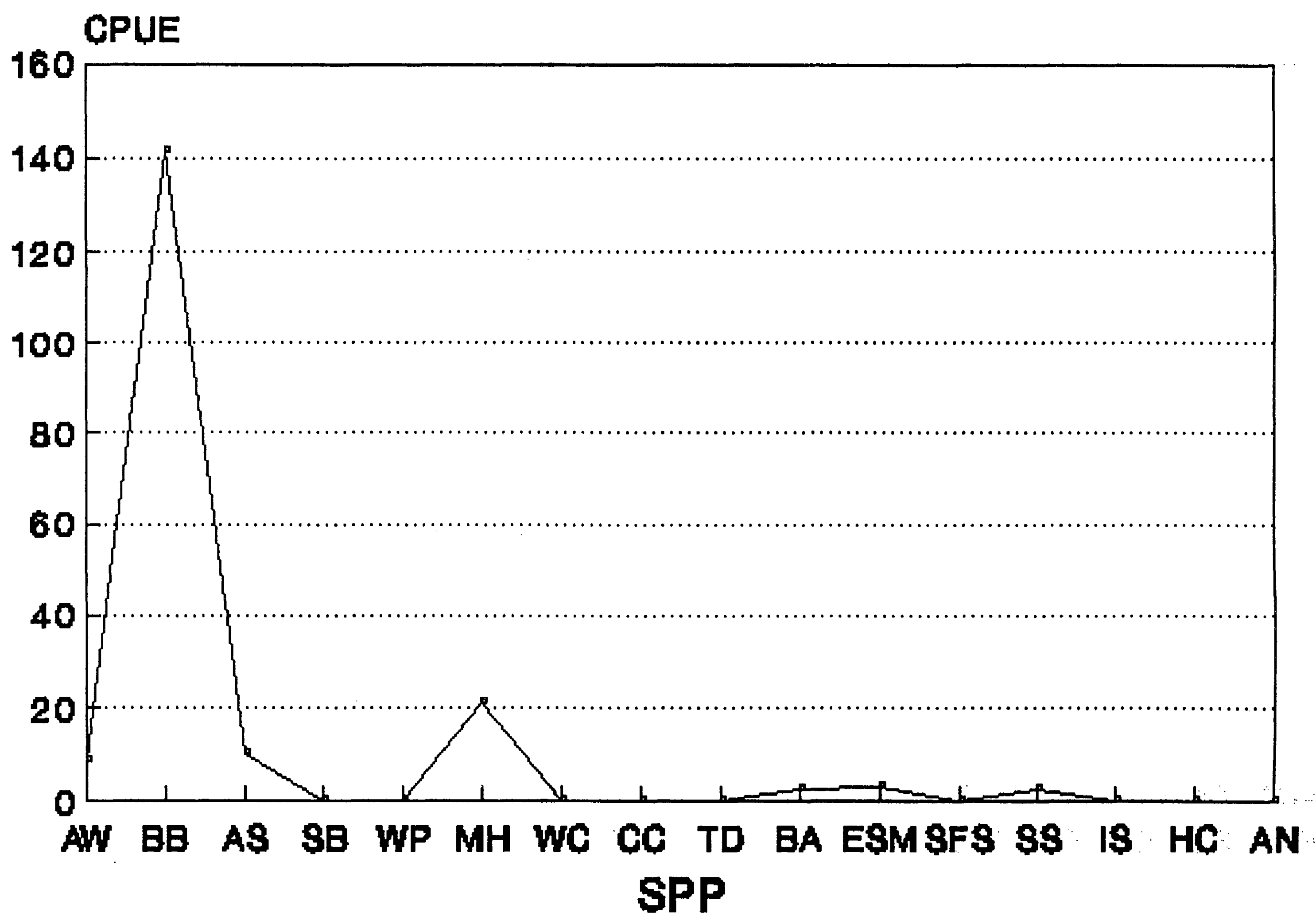
A PAMUNKEY 1983



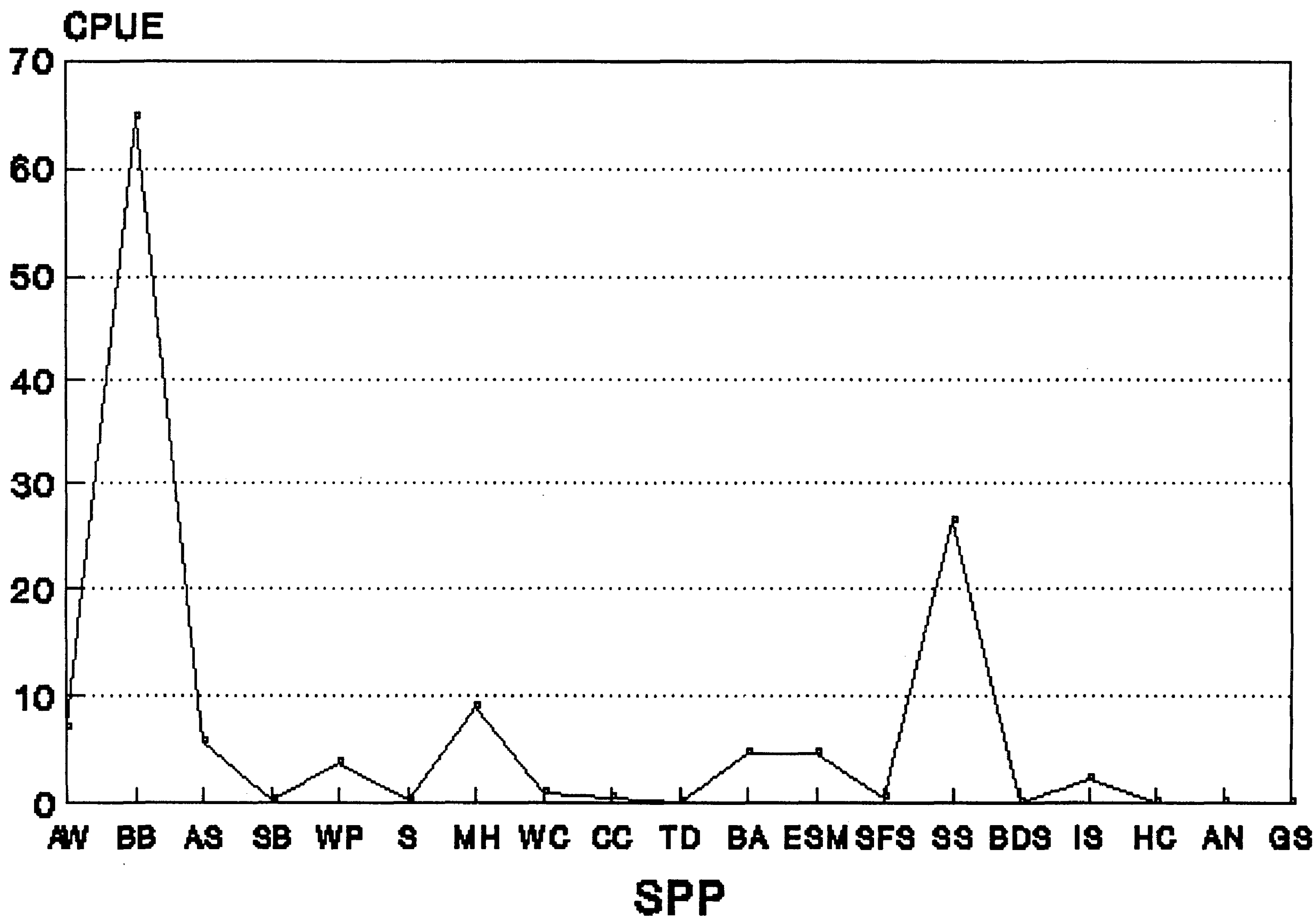
B PAMUNKEY 1984



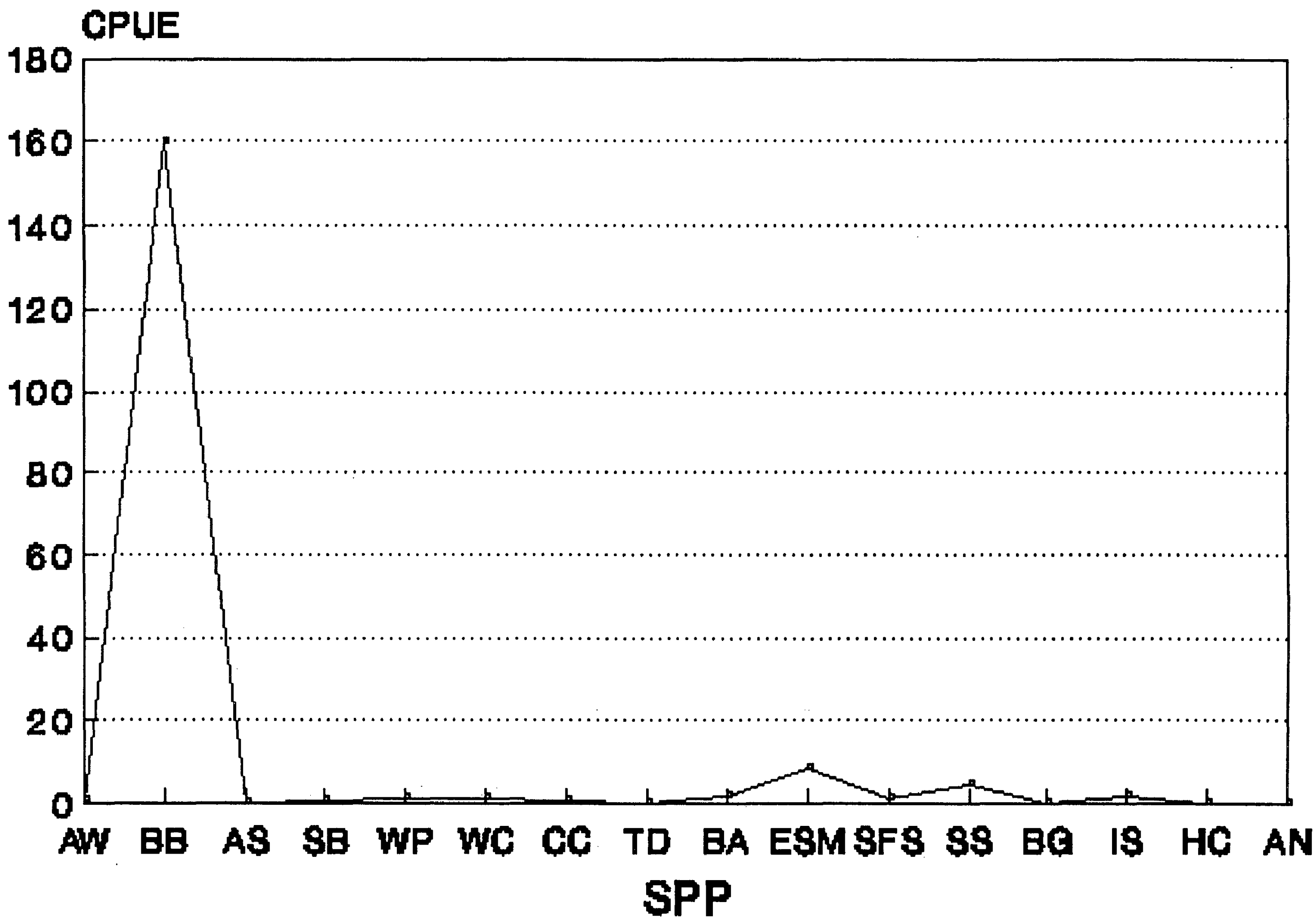
C PAMUNKEY 1985



D PAMUNKEY 1986



E PAMUNKEY 1987



F PAMUNKEY 1991

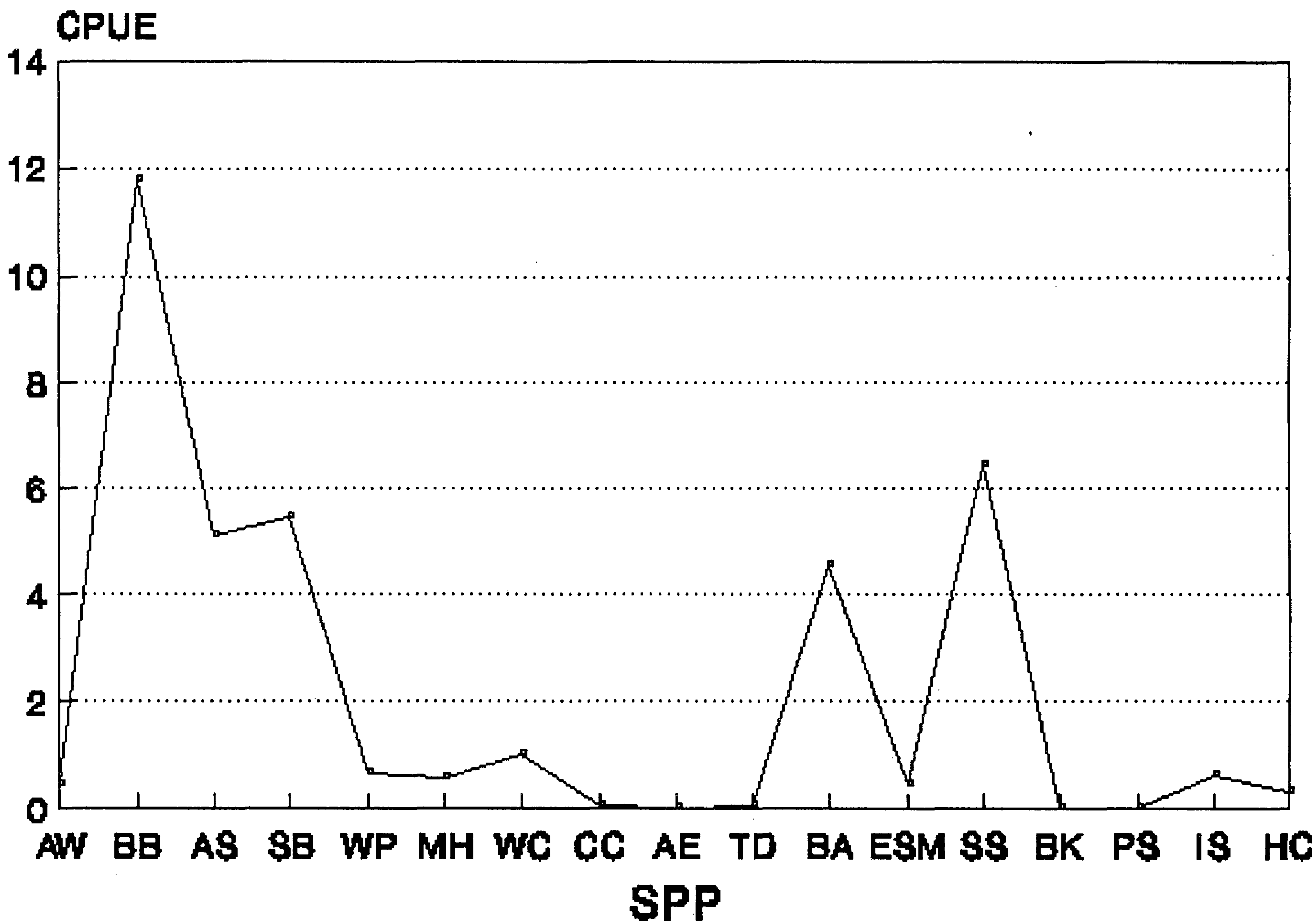
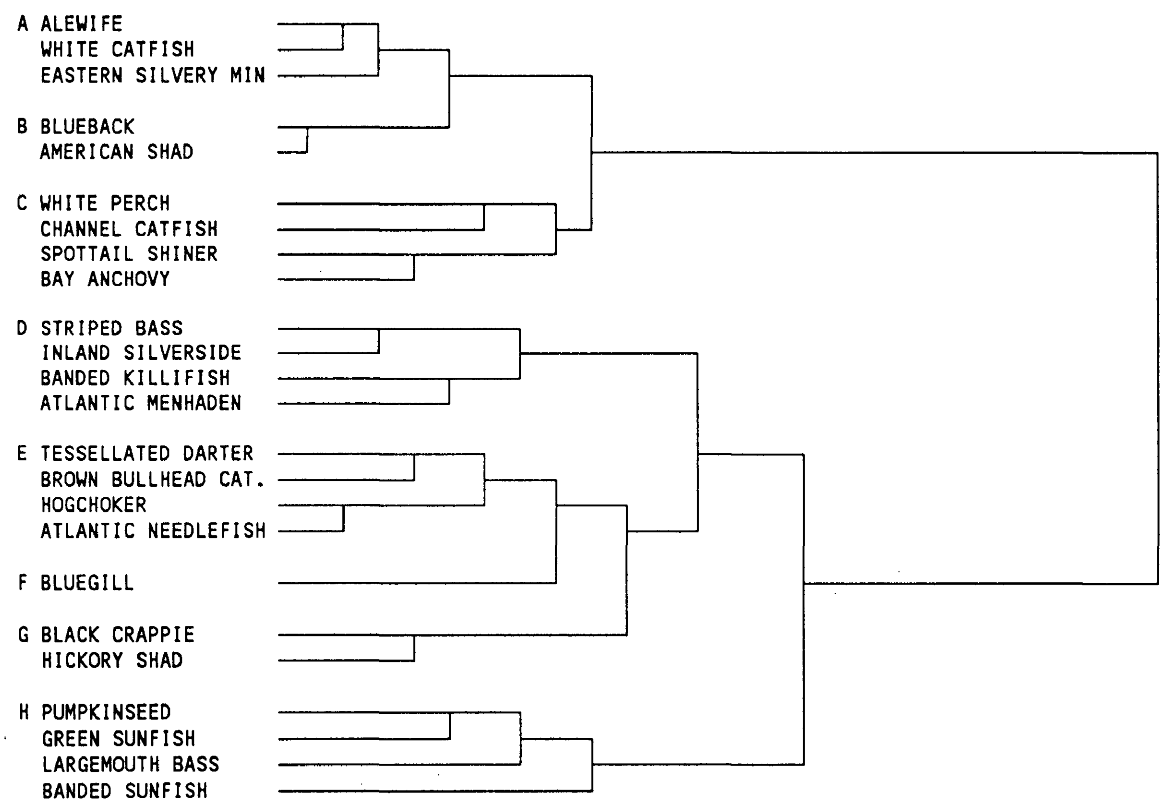


Figure 6(a,b). Dendograms for a) species and b) years produced by the Mattaponi cluster analysis.

MATTAPONI CLUSTER BY SPECIES



MATTAPONI CLUSTER BY YEARS

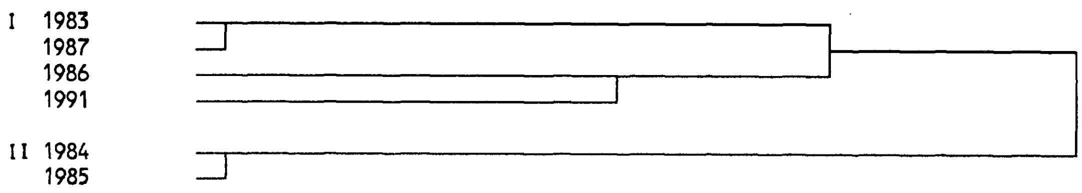
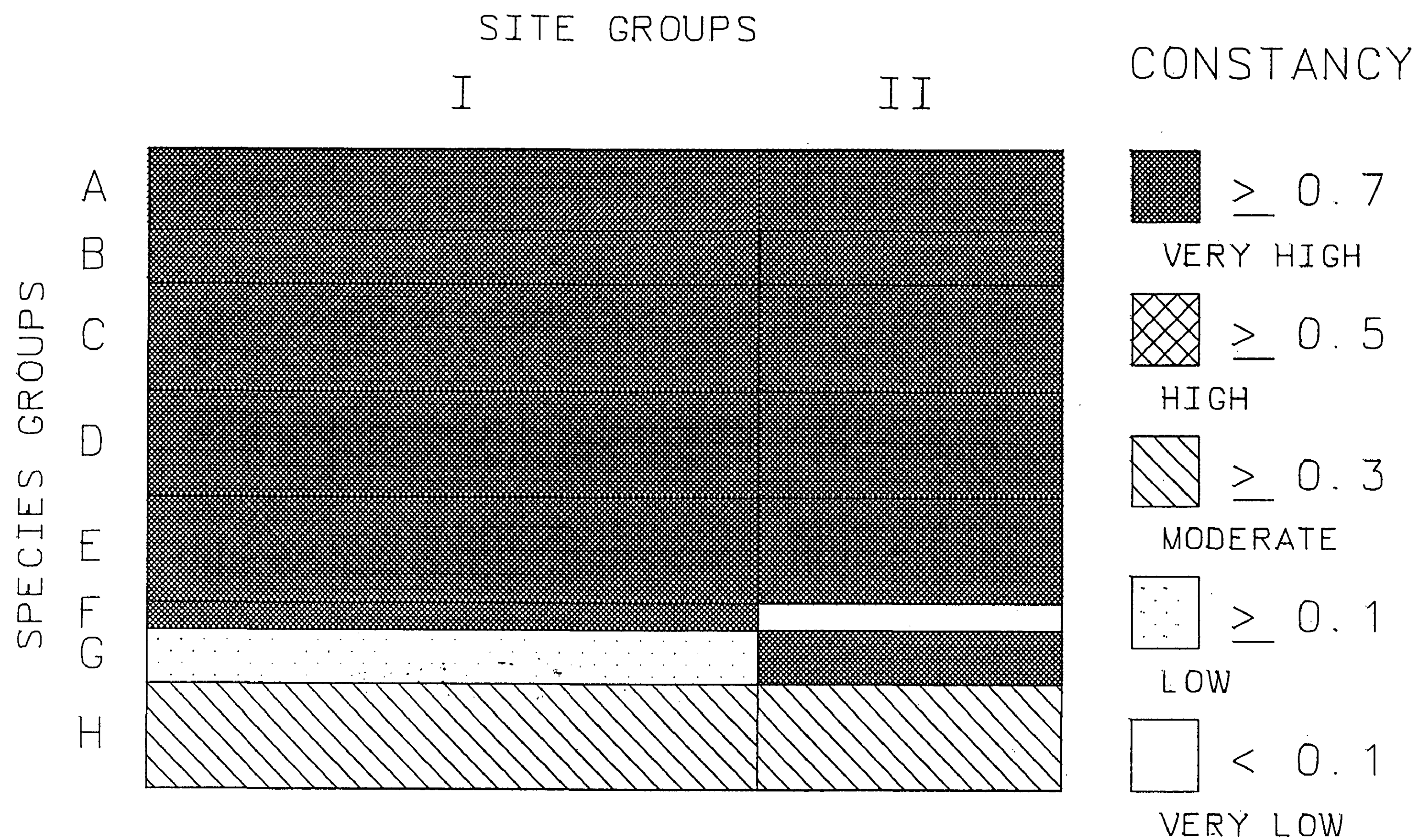
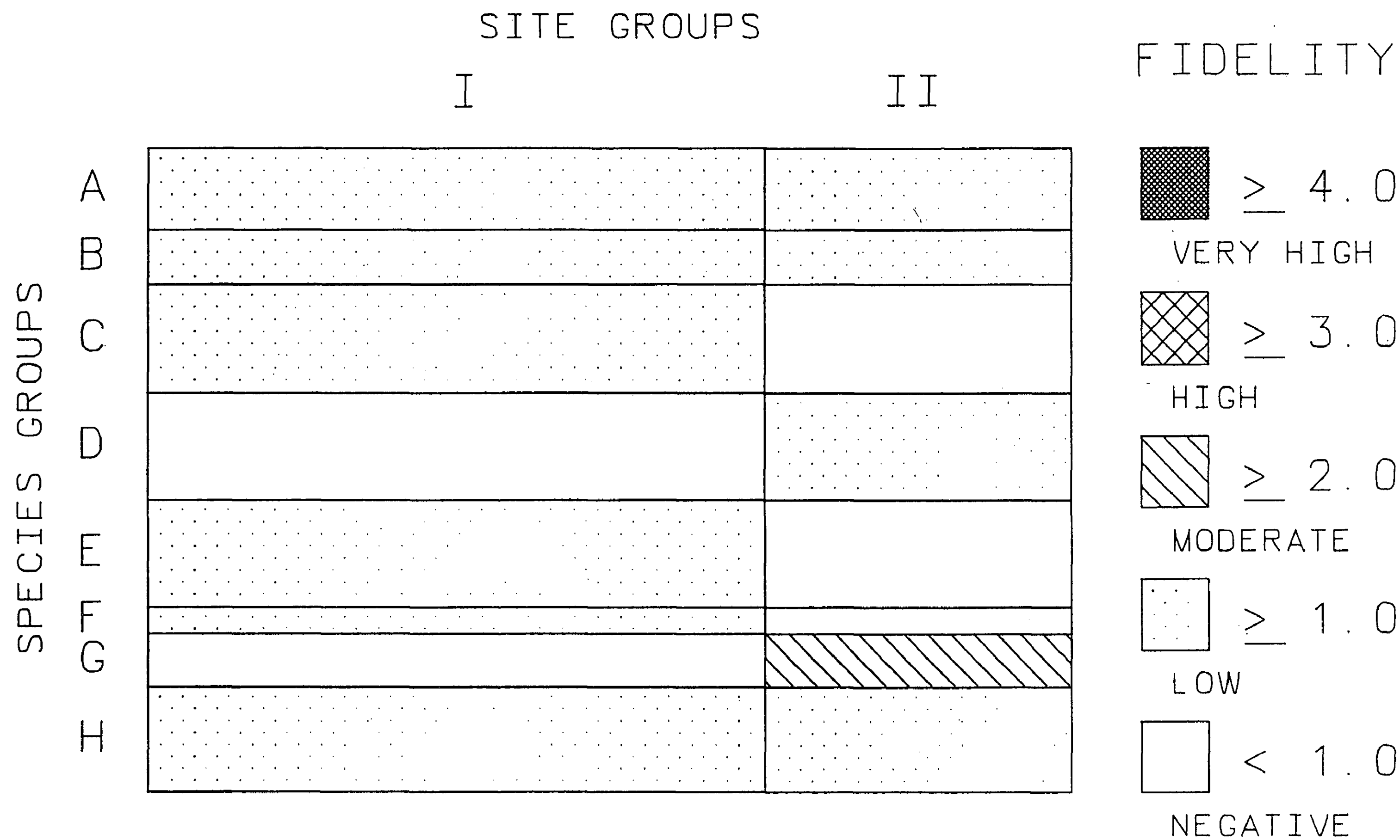


Figure 7(a,b). Nodal analysis of the species groups vs. the year groups from the Mattaponi a) constancy index and b) fidelity index.


SITE GROUPS
I
II
SPECIES GROUPS
A
B
C
D
E
F
G
H
CONSTANCY
≥ 0.7
VERY HIGH
≥ 0.5
HIGH
≥ 0.3
MODERATE
≥ 0.1
LOW
< 0.1
VERY LOW

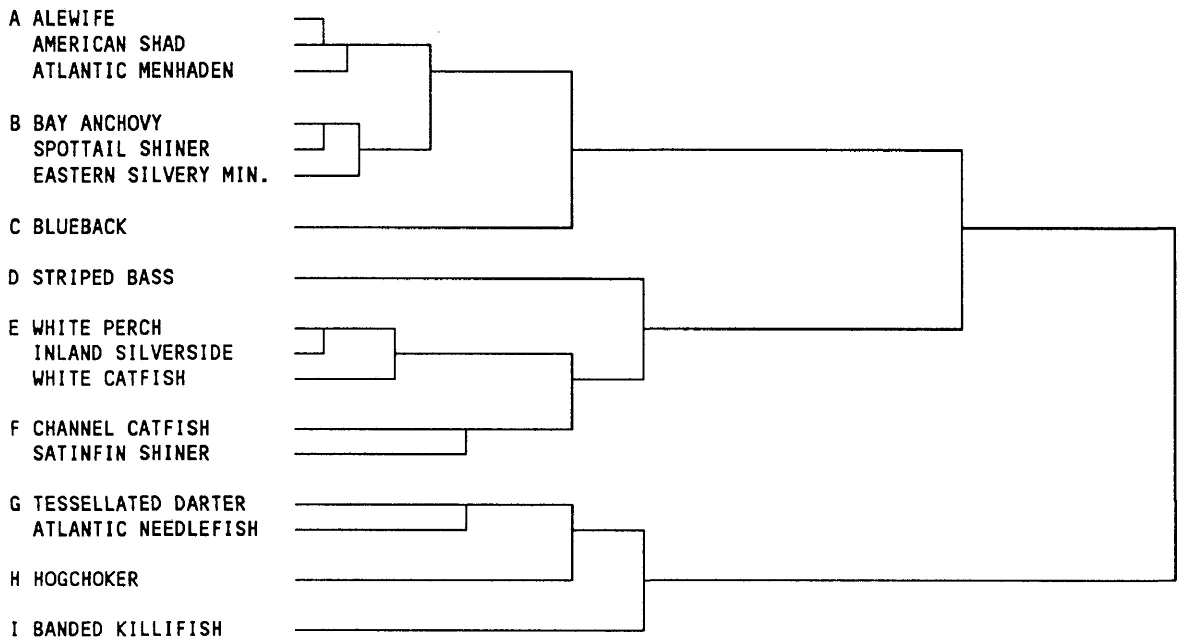
MATTAPONI


SITE GROUPS
I
II
SPECIES GROUPS
A
B
C
D
E
F
G
H
FIDELITY
≥ 4.0
VERY HIGH
≥ 3.0
HIGH
≥ 2.0
MODERATE
≥ 1.0
LOW
< 1.0
NEGATIVE

MATTAPONI

Figure 8(a,b). Dendograms of a) species and b) years produced by the Pamunkey cluster analysis.

PAMUNKEY CLUSTER BY SPECIES



PAMUNKEY CLUSTER BY YEARS

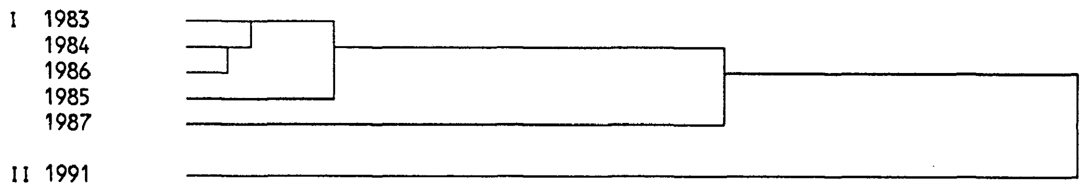
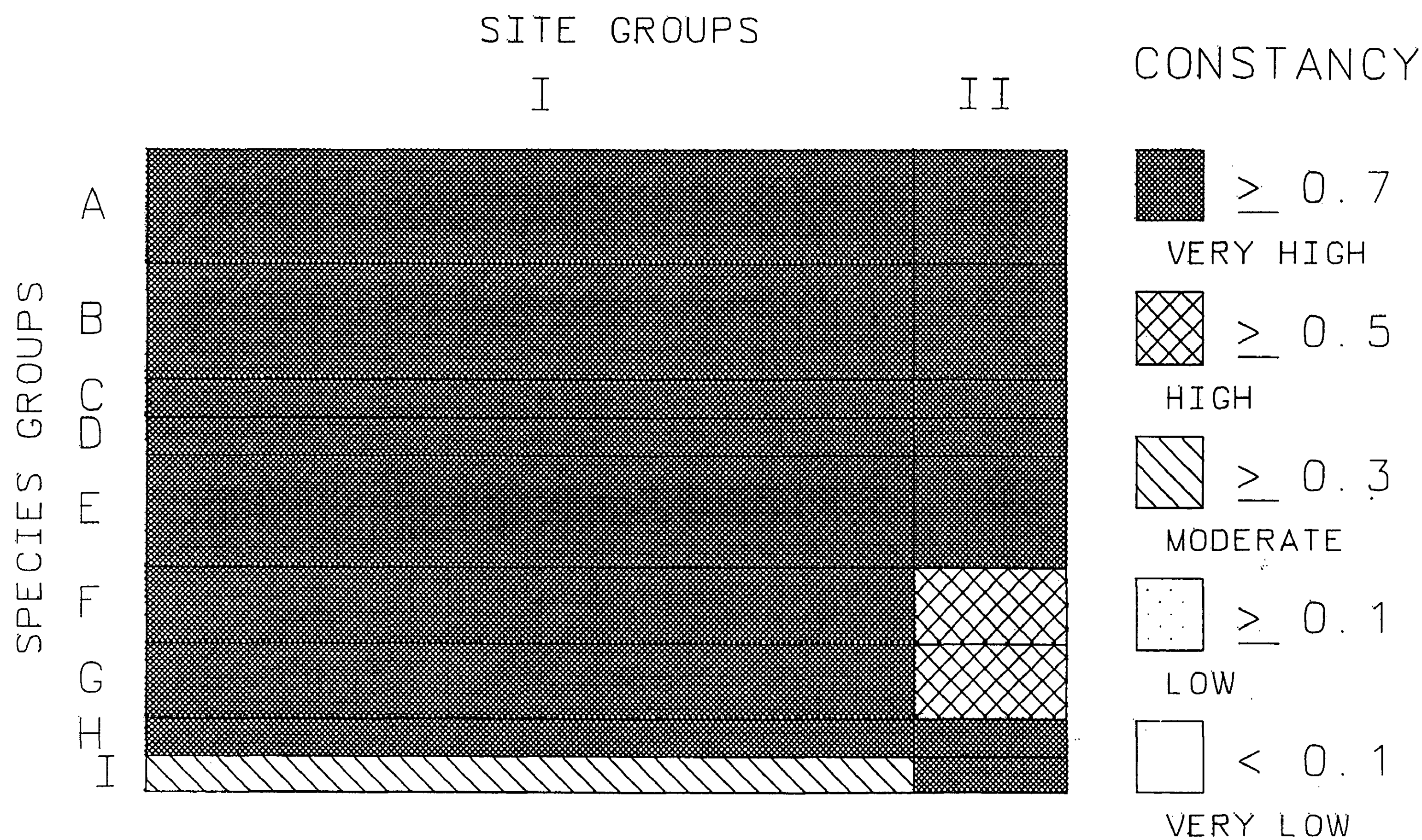
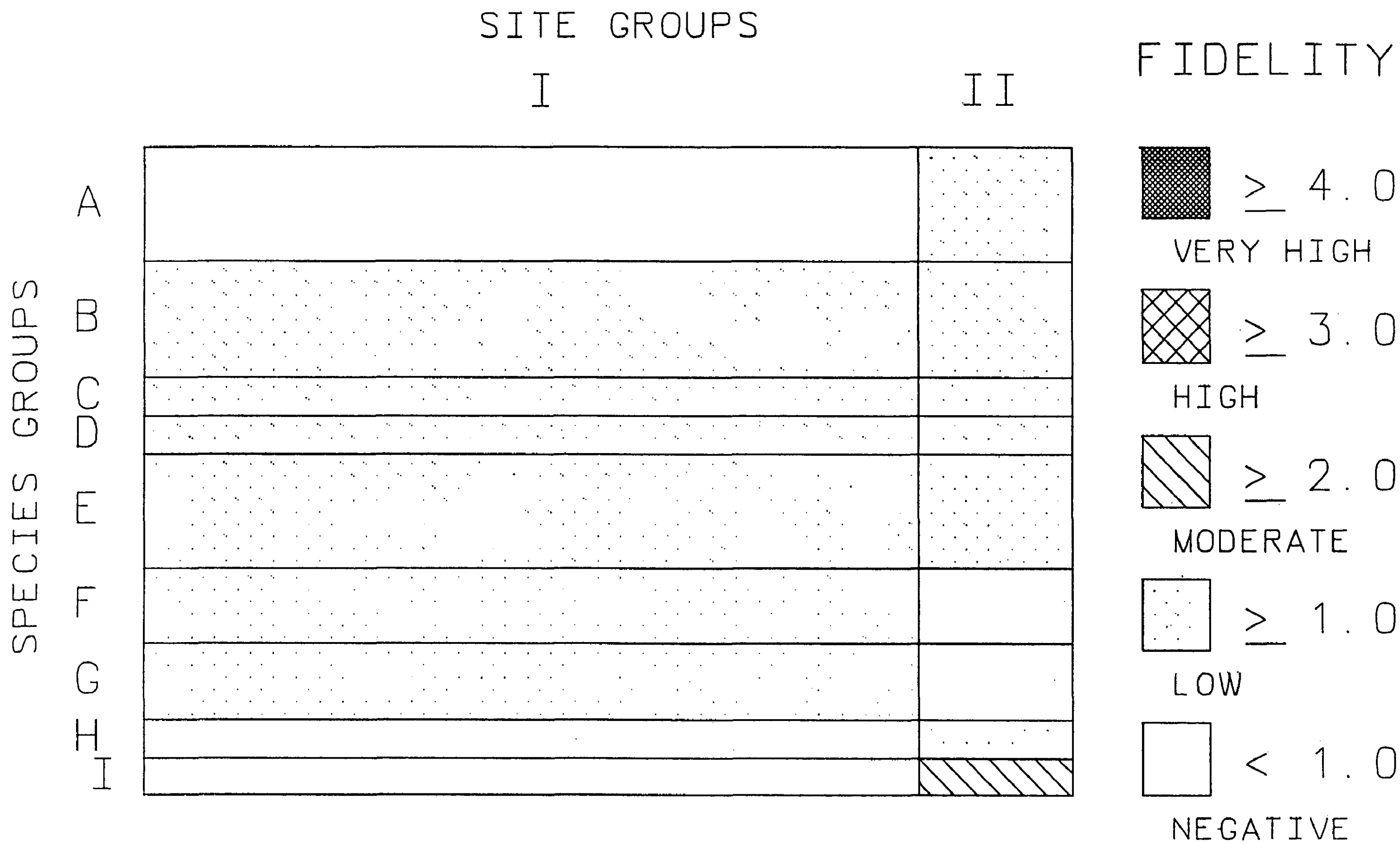


Figure 9(a,b). Nodal analysis of the species groups vs. the year groups from the Pamunkey a) constancy index and b) fidelity index.


SITE GROUPS
I
II
SPECIES GROUPS
A
B
C
D
E
F
G
H
I
CONSTANCY
≥ 0.7
VERY HIGH
≥ 0.5
HIGH
≥ 0.3
MODERATE
≥ 0.1
LOW
< 0.1
VERY LOW

Pamunkey

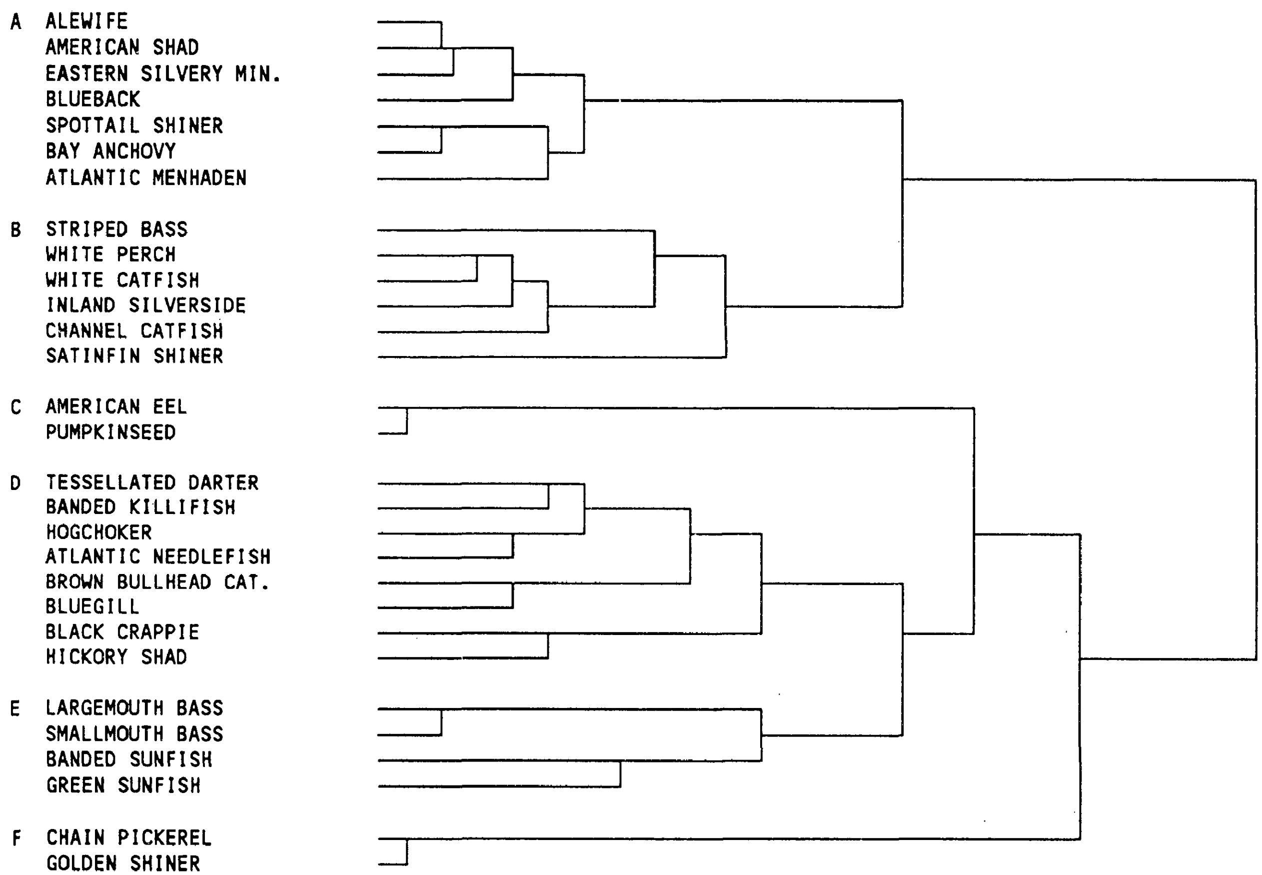


SITE GROUPS
I
II
SPECIES GROUPS
A
B
C
D
E
F
G
H
I
FIDELITY
≥ 4.0
VERY HIGH
≥ 3.0
HIGH
≥ 2.0
MODERATE
≥ 1.0
LOW
< 1.0
NEGATIVE

Pamunkey

Figure 10(a,b). Dendograms of a) species and b) years produced by the combined Mattaponi and Pamunkey cluster analysis.

MATTAPONI AND PAMUNKEY CLUSTER BY SPECIES



MATTAPONI AND PAMUNKEY CLUSTER BY YEARS

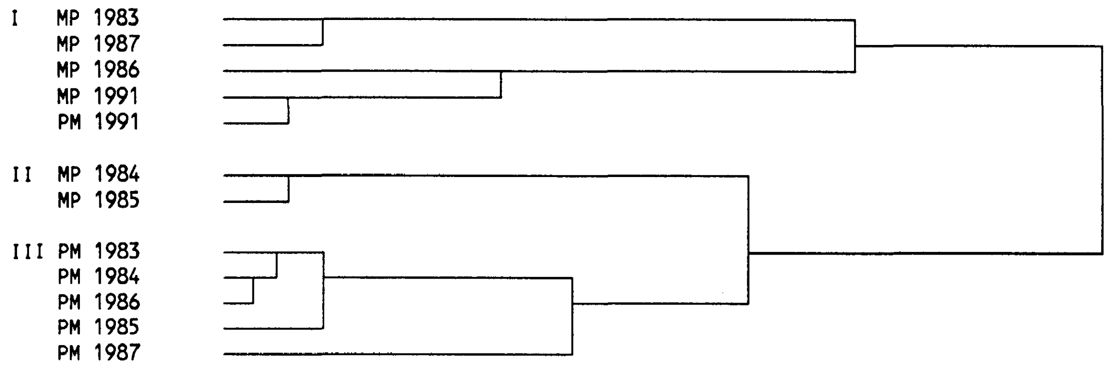
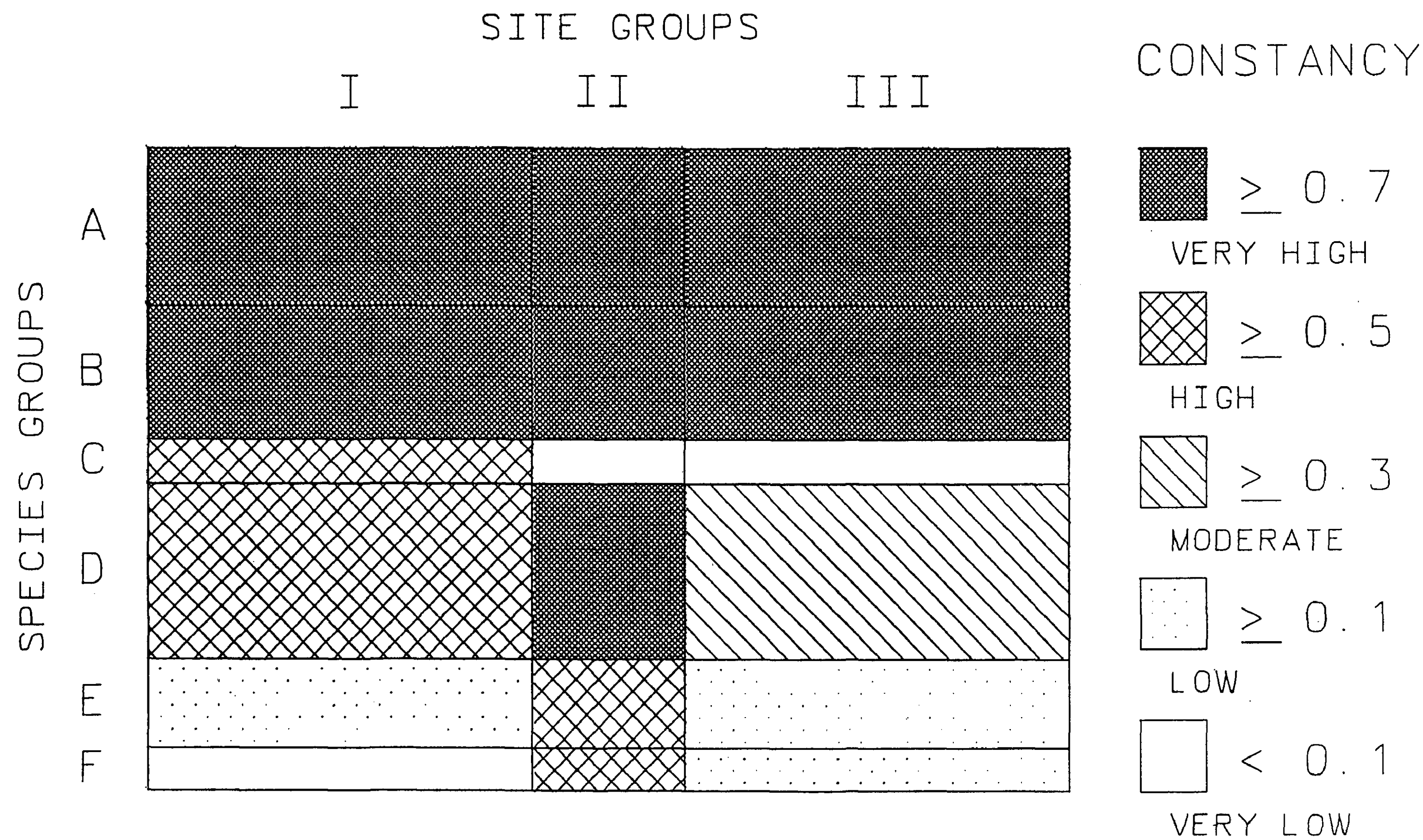
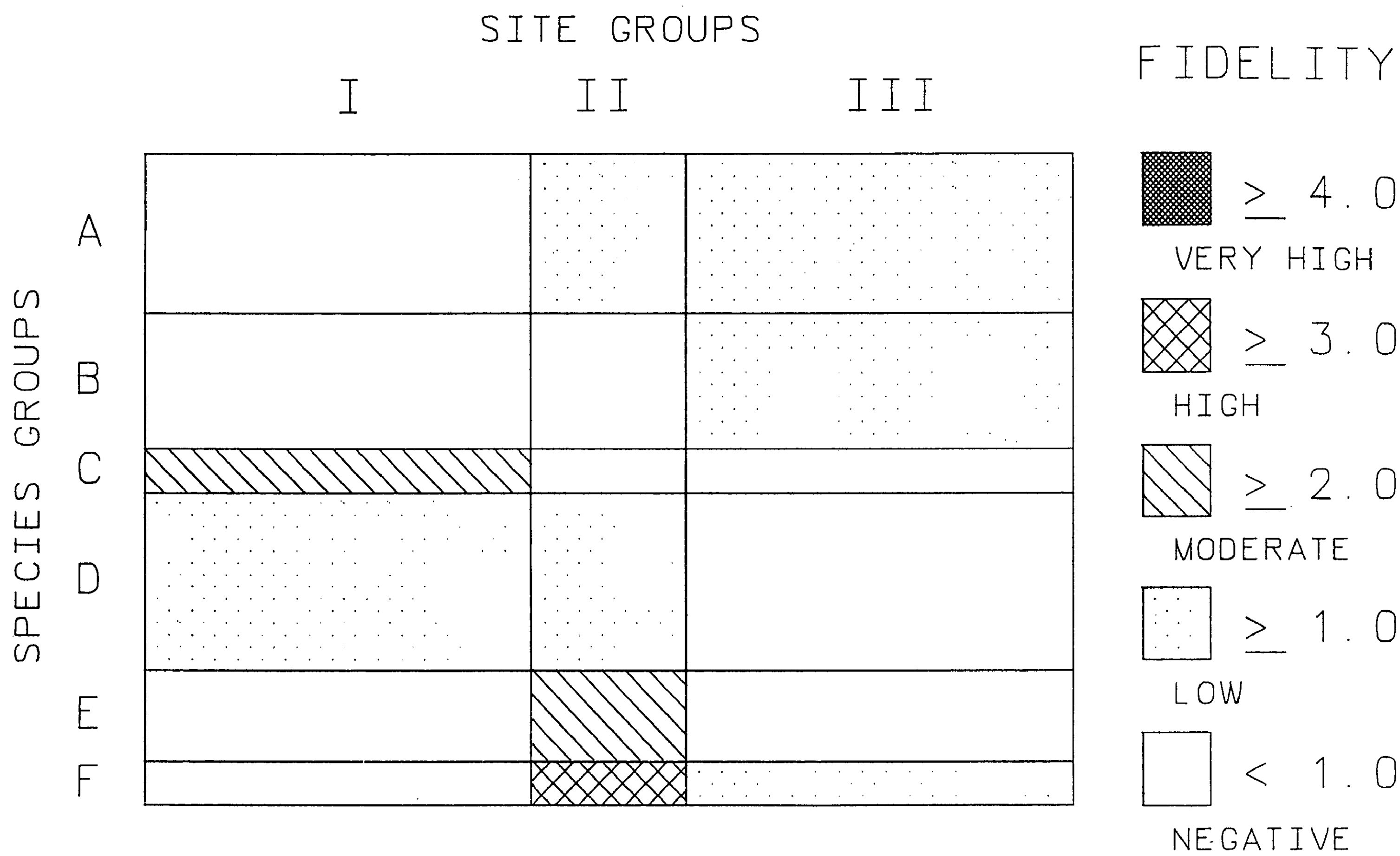


Figure 11(a,b). Nodal analysis of the species groups vs. the year groups from the Mattaponi and the Pamunkey combined a) constancy index and b) fidelity index.



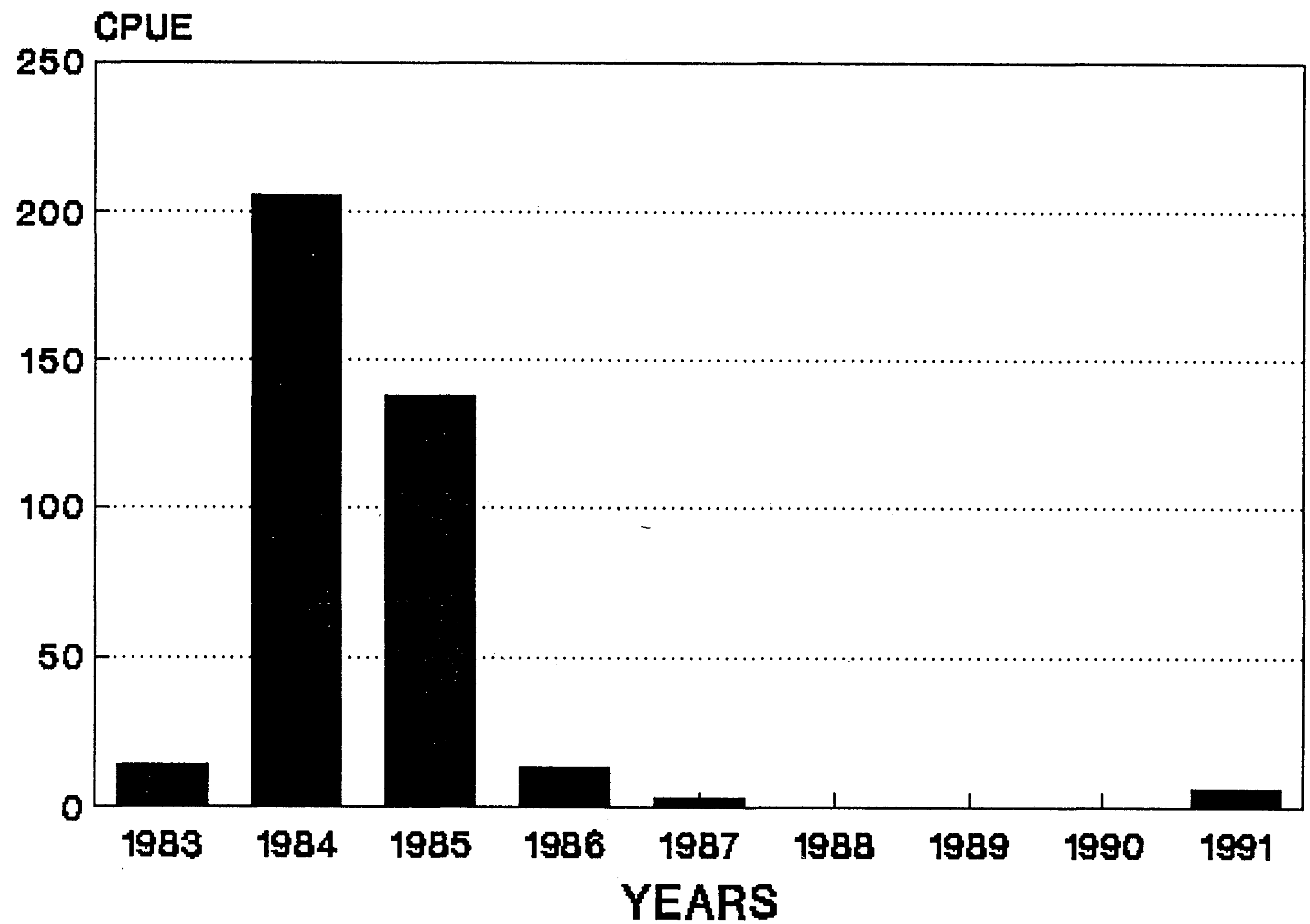
MATTAPONI AND PAMUNKEY

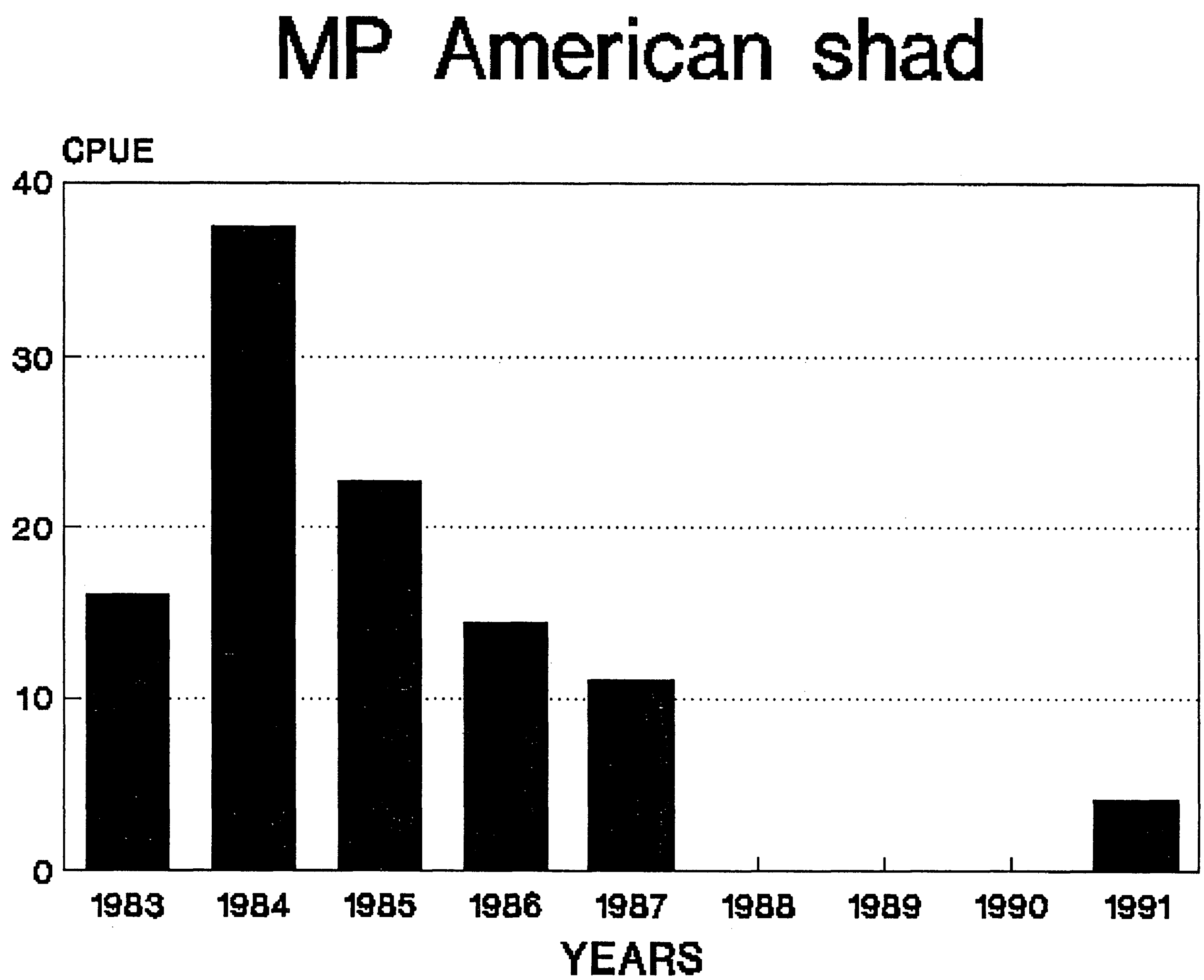


MATTAPONI AND PAMUNKEY

Figure 12(a-c). The CPUE of the top three most abundant species found in the Mattaponi a) blueback, b) American shad, and c) Eastern silvery minnow.

MP bluebacks




MP American shad
CPUE
40
30
20
10
0
1983
1984
1985
1986
1987
1988
1989
1990
1991
YEARS

MP Eastern silvery minnow

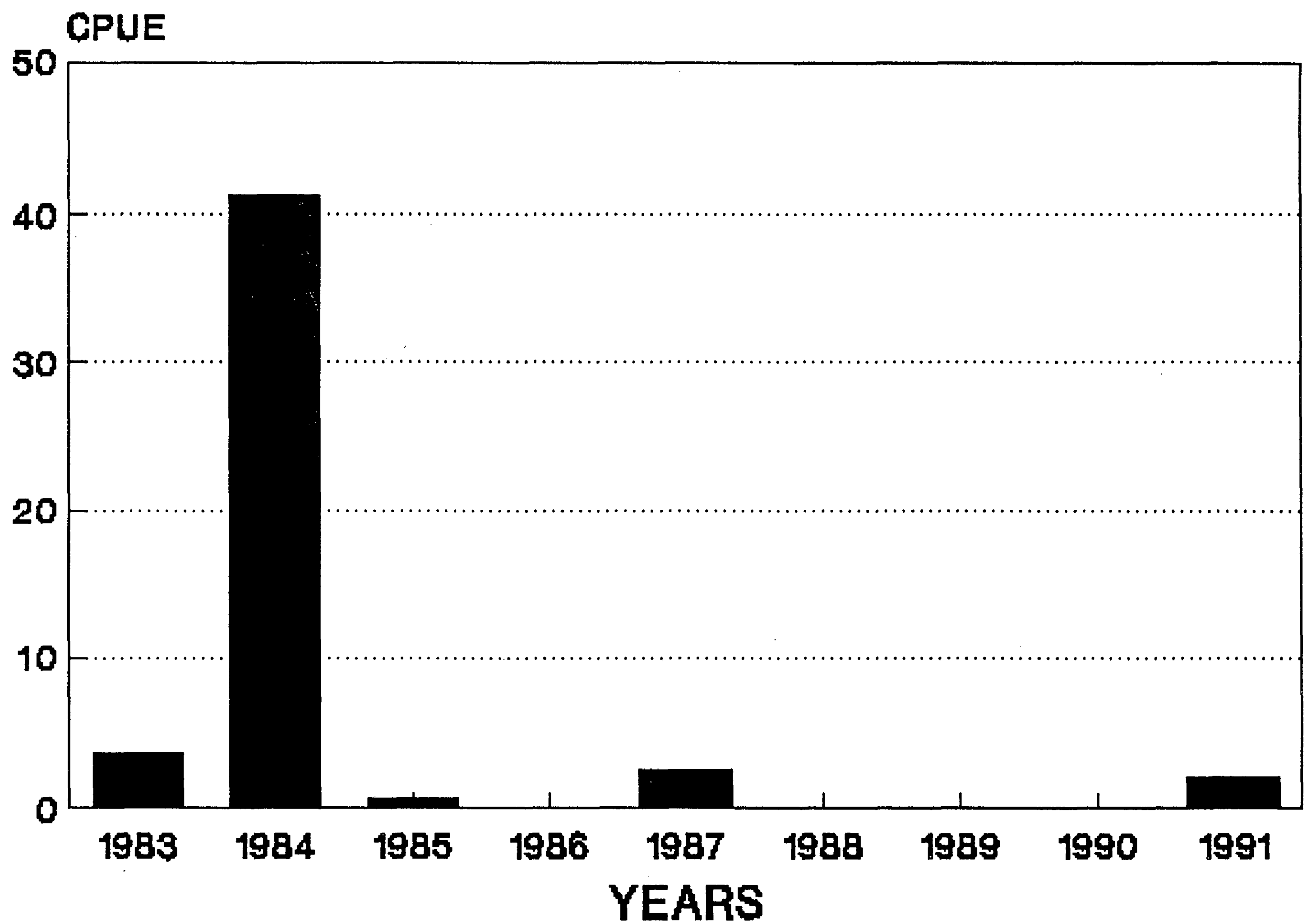
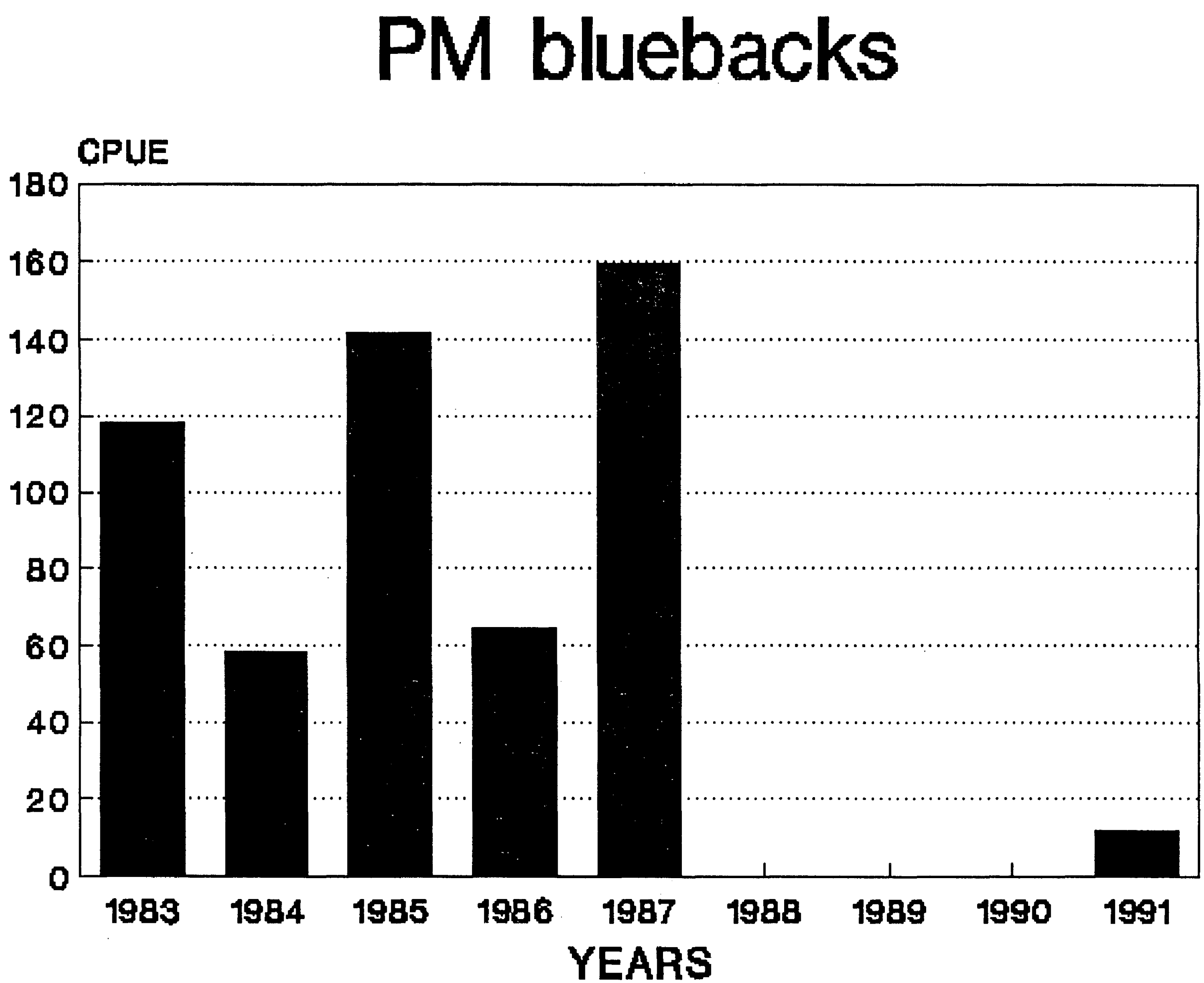
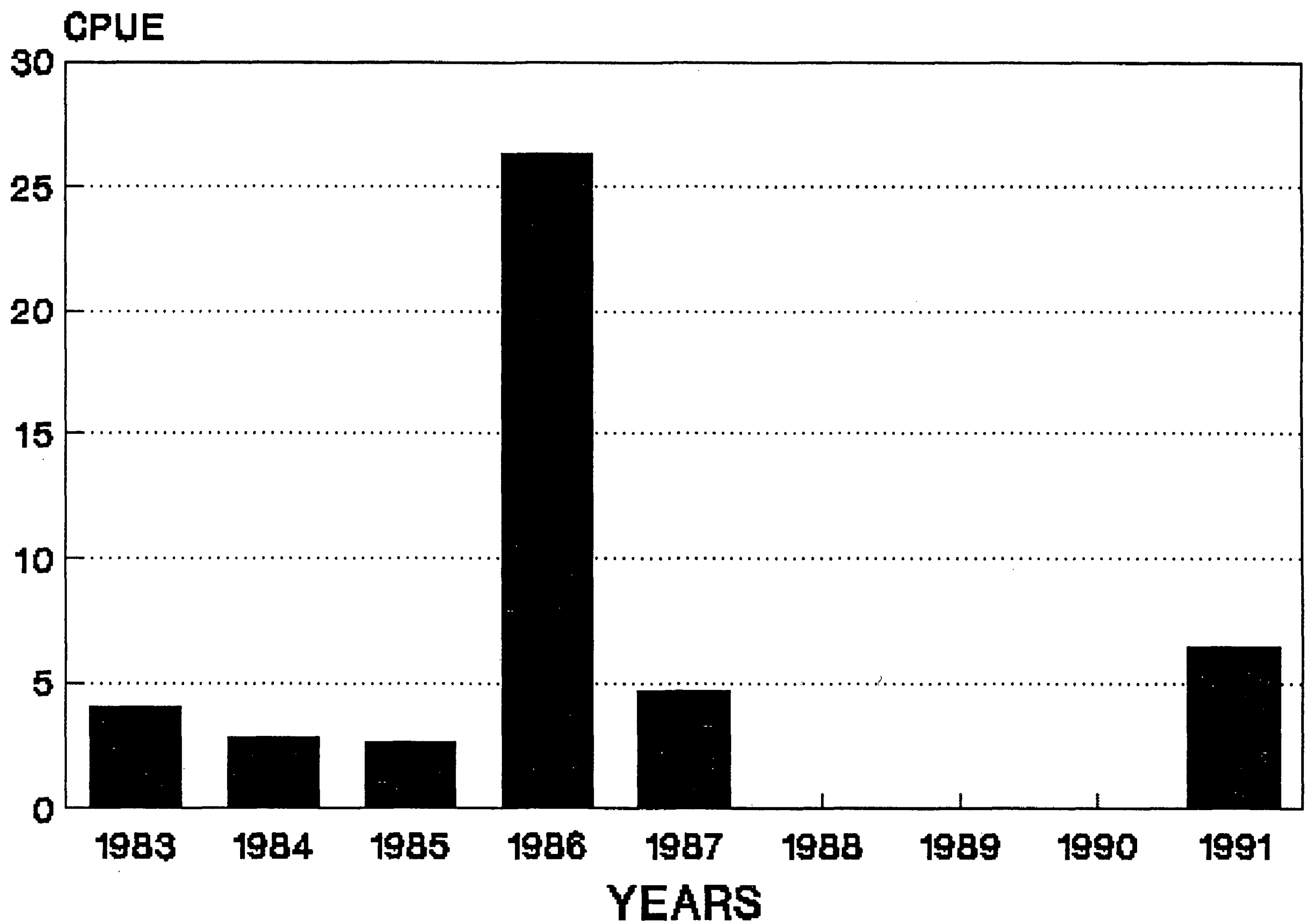


Figure 13(a-c). The CPUE of the top three most abundant species found in the Pamunkey a) blueback, b) spottail shiner, and c) Atlantic menhaden.


PM bluebacks
CPUE
180
160
140
120
100
80
60
40
20
0
1983
1984
1985
1986
1987
1988
1989
1990
1991
YEARS

PM spottail shiners



PM Atlantic menhaden

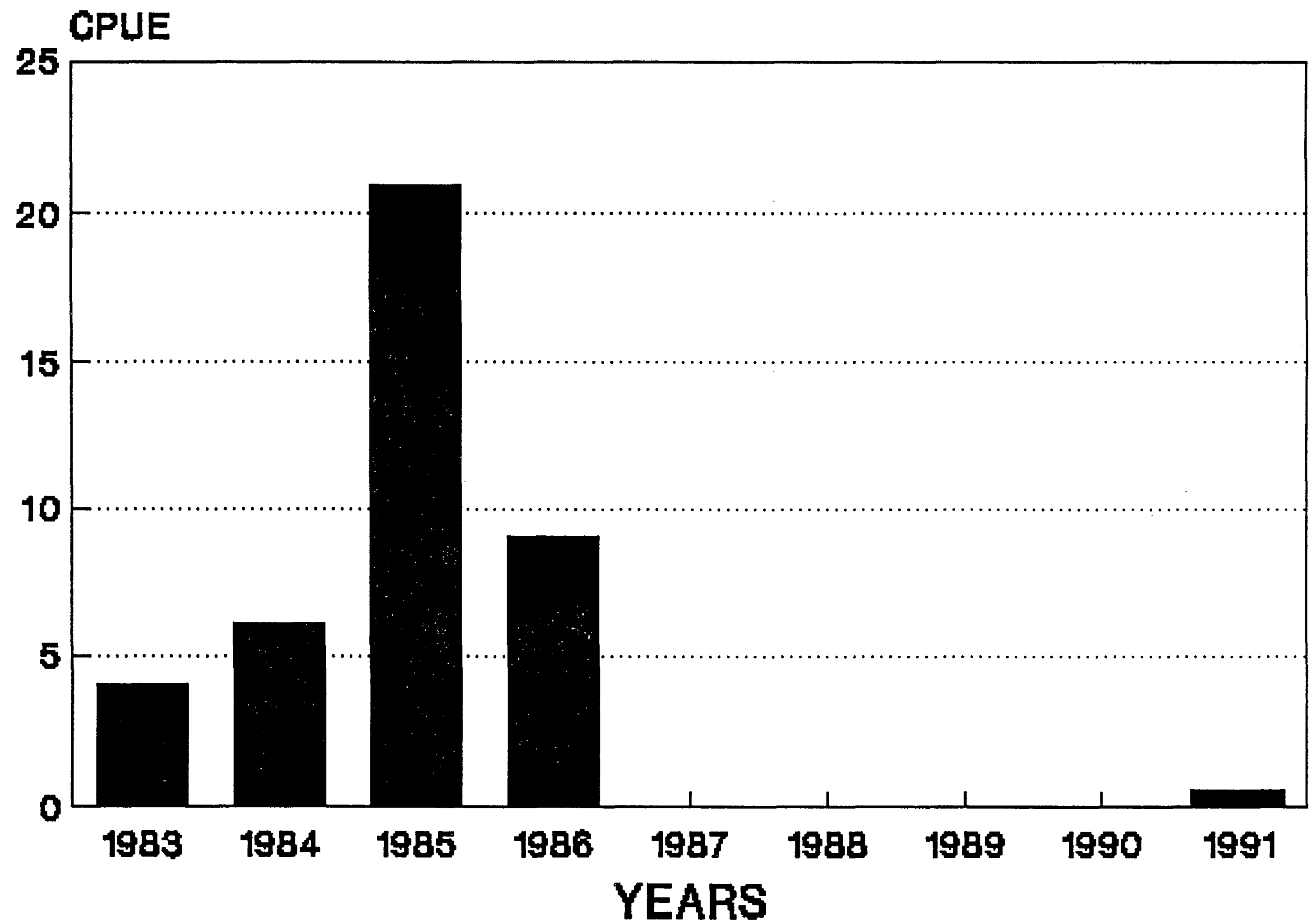
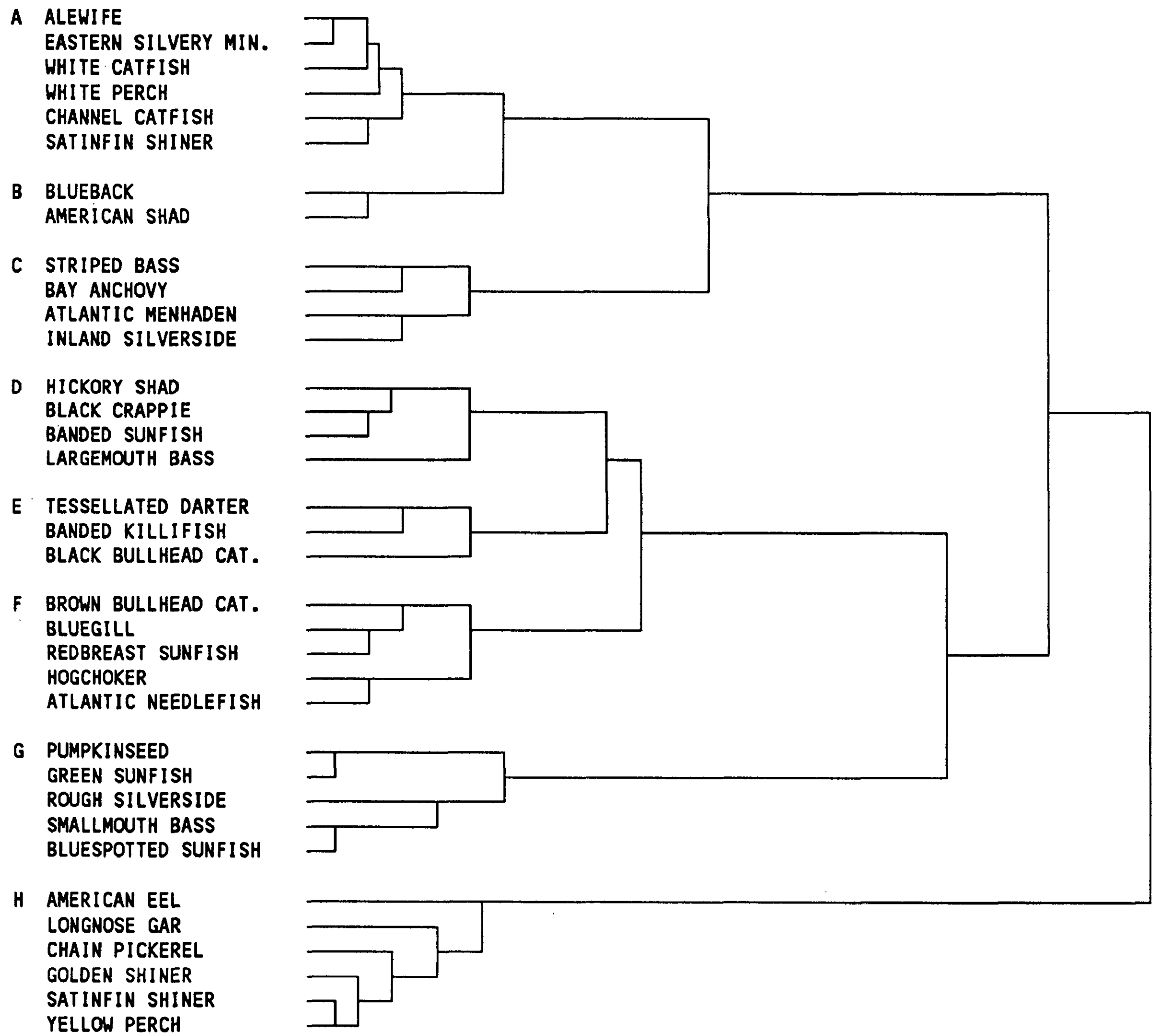
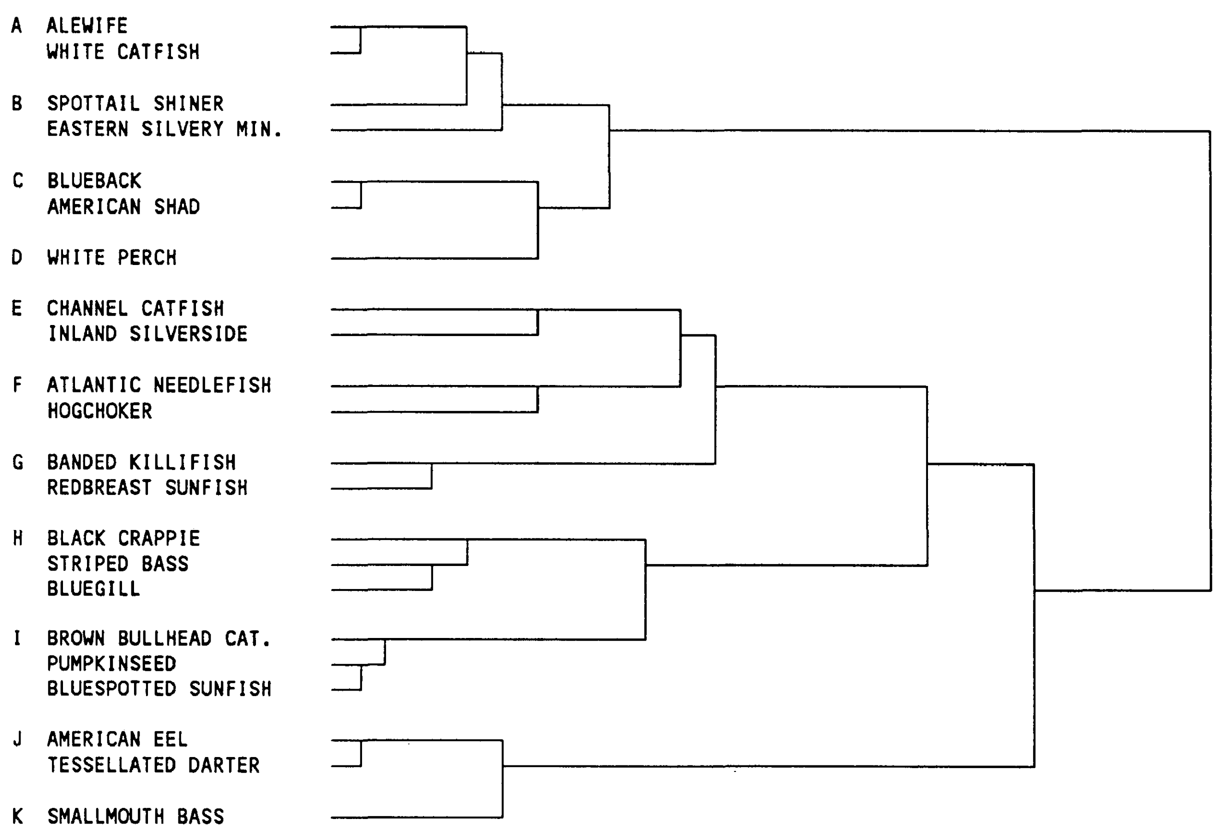


Figure 14(a-g). Dendograms of the species lists produced from the spatial cluster analysis for the Mattaponi a) all years combined, b) 1983, c) 1984, d) 1985, e) 1986, f) 1987, and g) 1991.

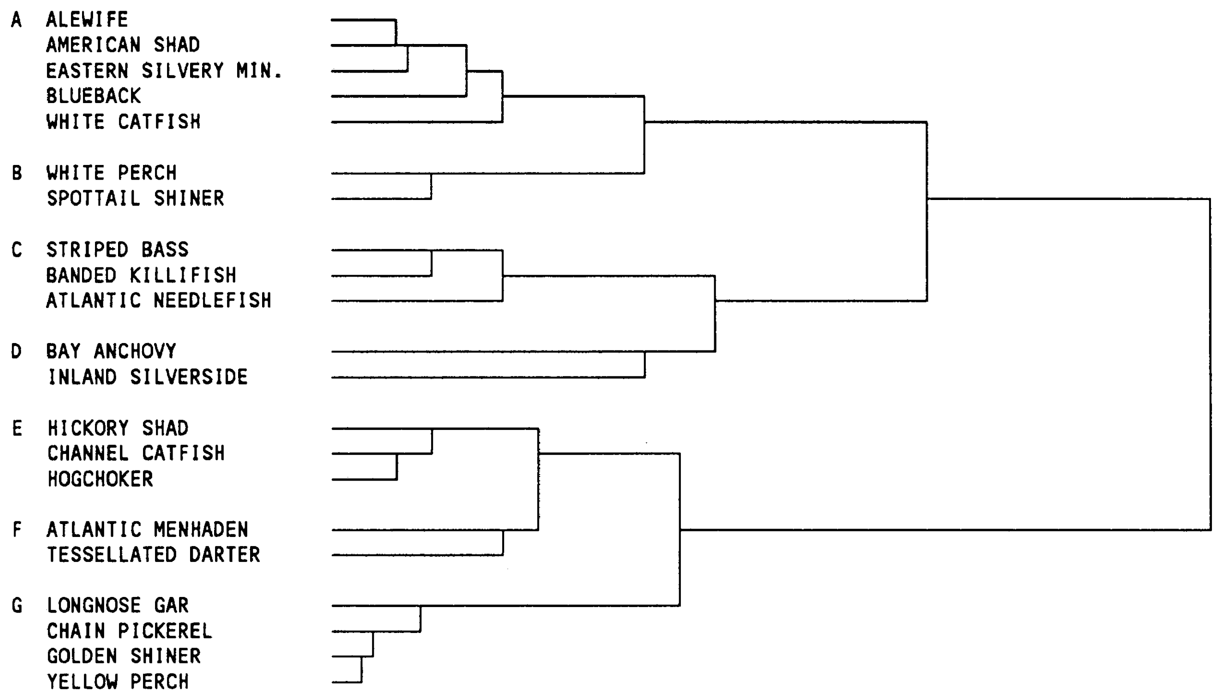
MATTAPONI SPATIAL CLUSTER FOR ALL YEARS COMBINED CLUSTER BY SPECIES



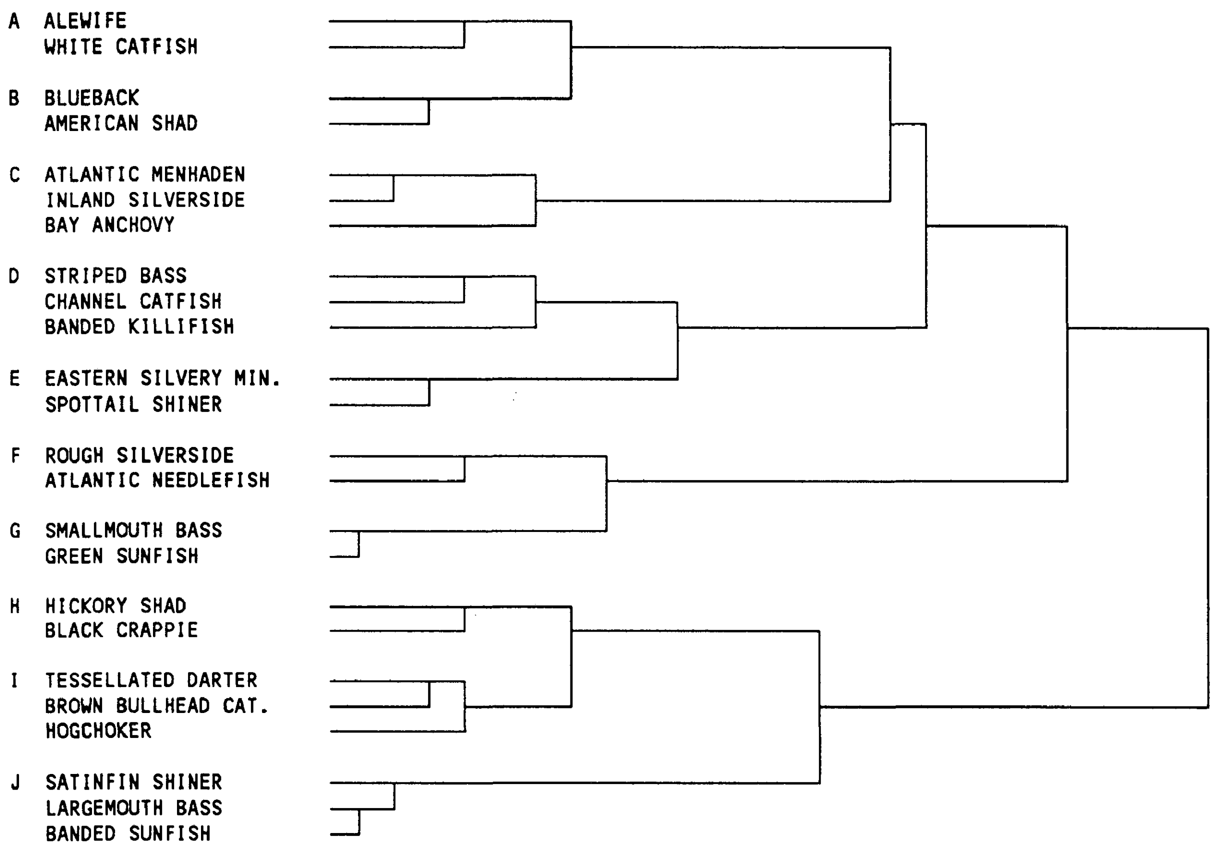
MATTAPONI 1983 CLUSTER BY SPECIES



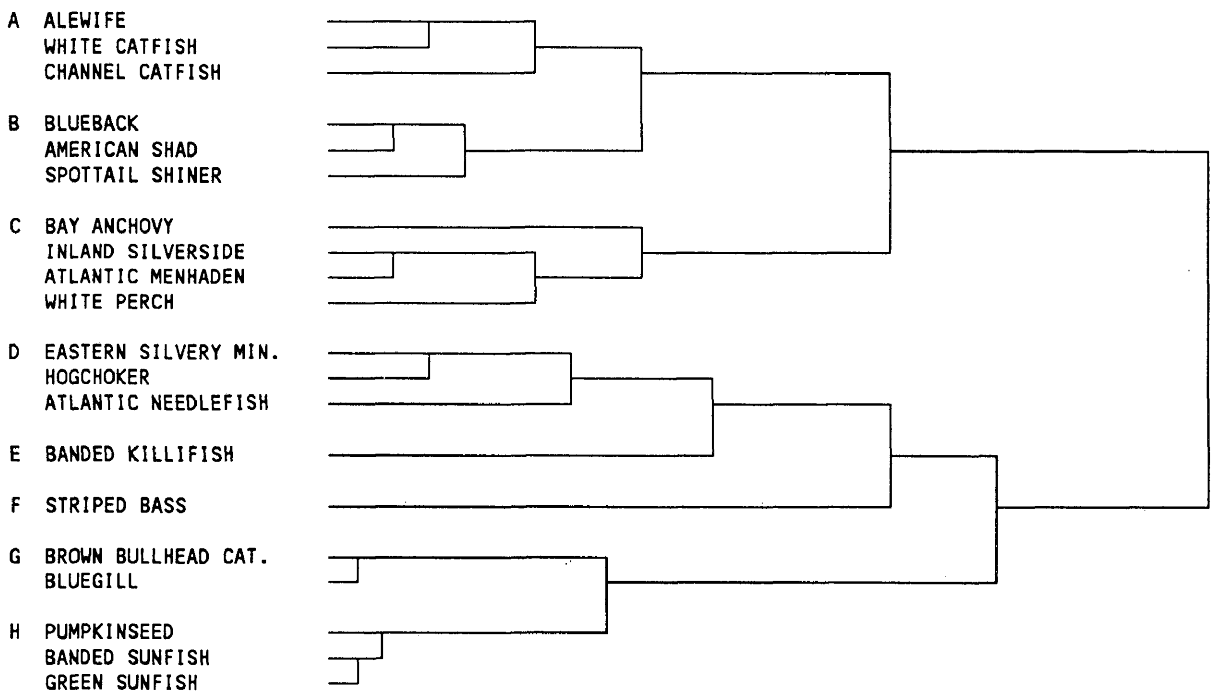
MATTAPONI 1984 CLUSTER BY SPECIES



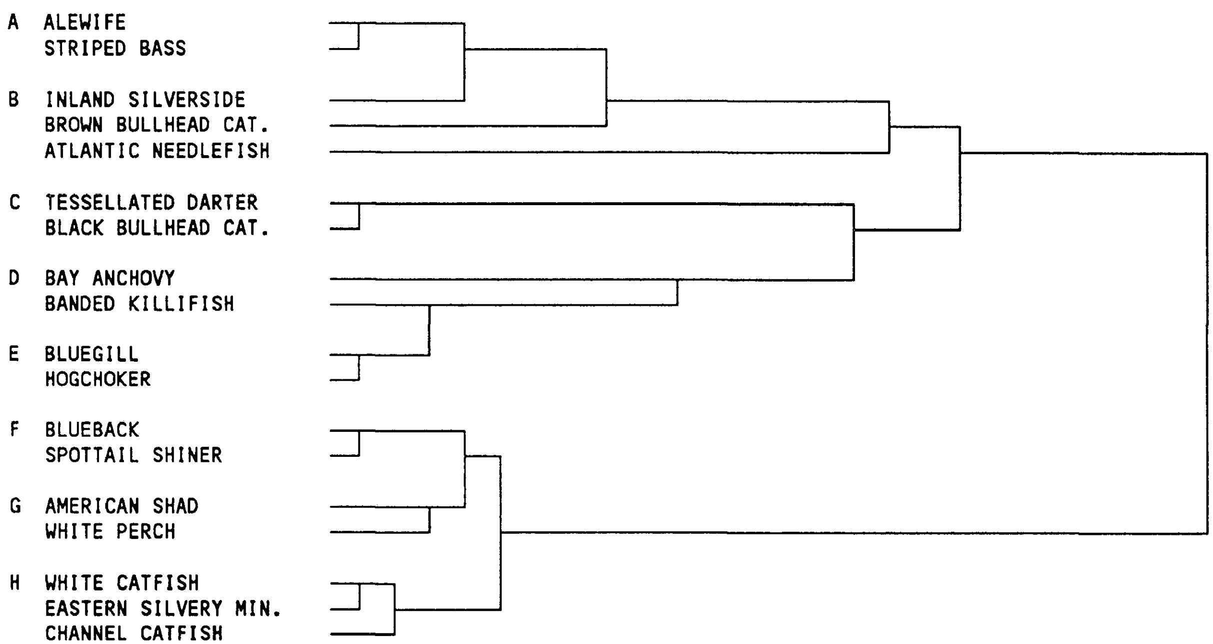
MATTAPONI 1985 CLUSTER BY YEARS



MATTAPONI 1986 CLUSTER BY SPECIES



MATTAPONI 1987 CLUSTER BY SPECIES



MATTAPONI 1991 CLUSTER BY SPECIES

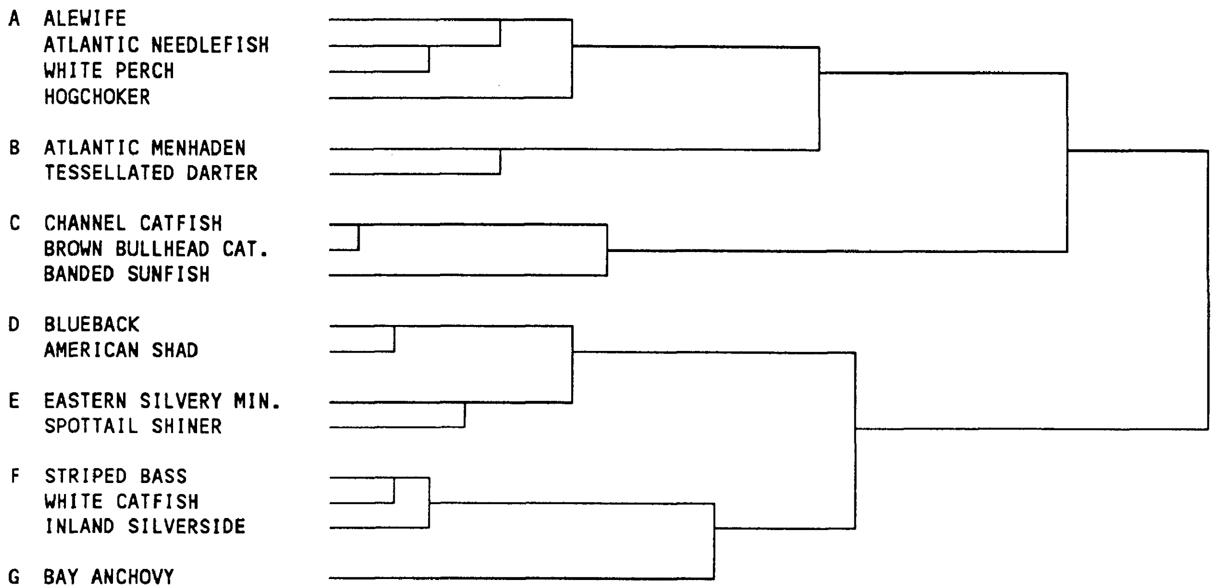
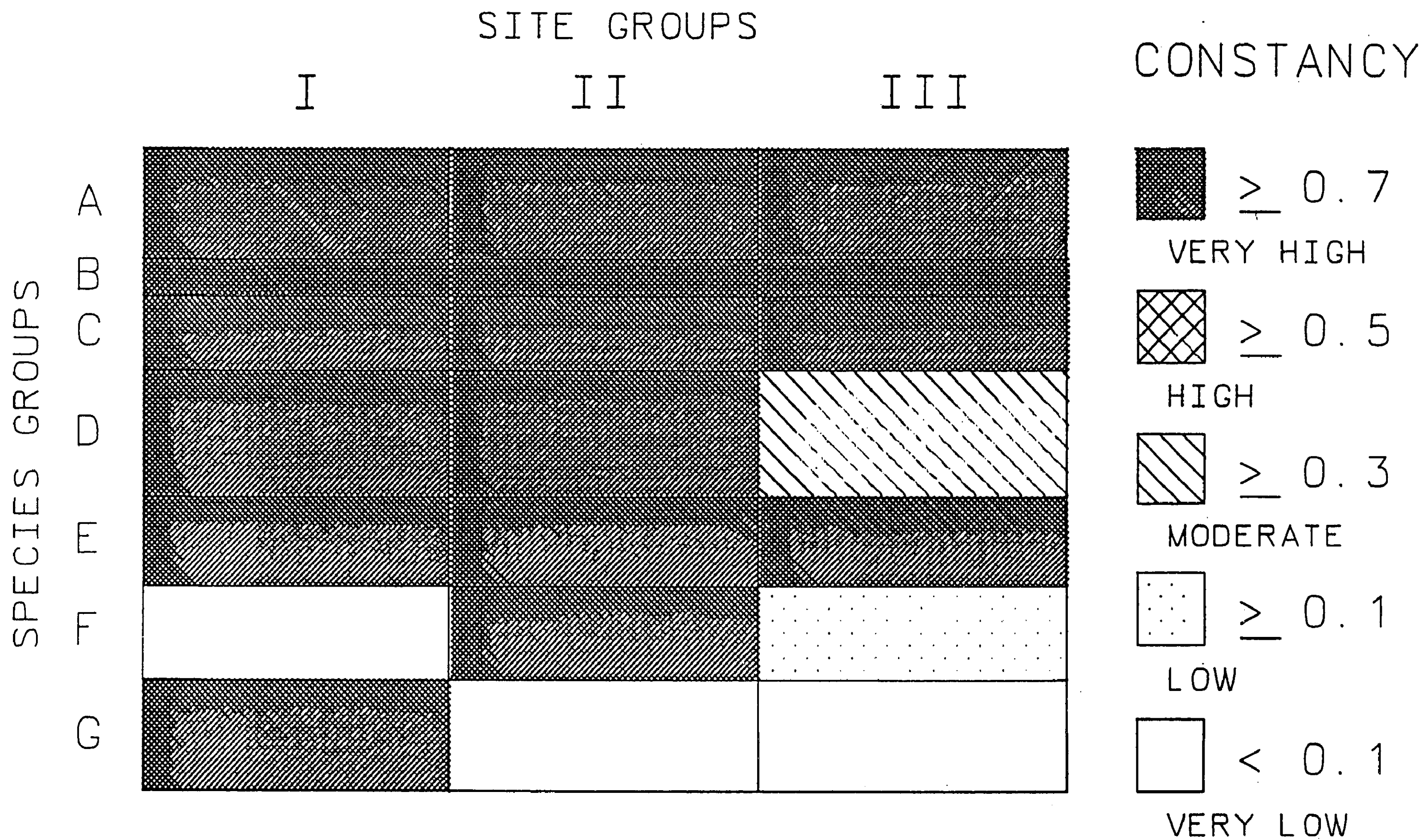
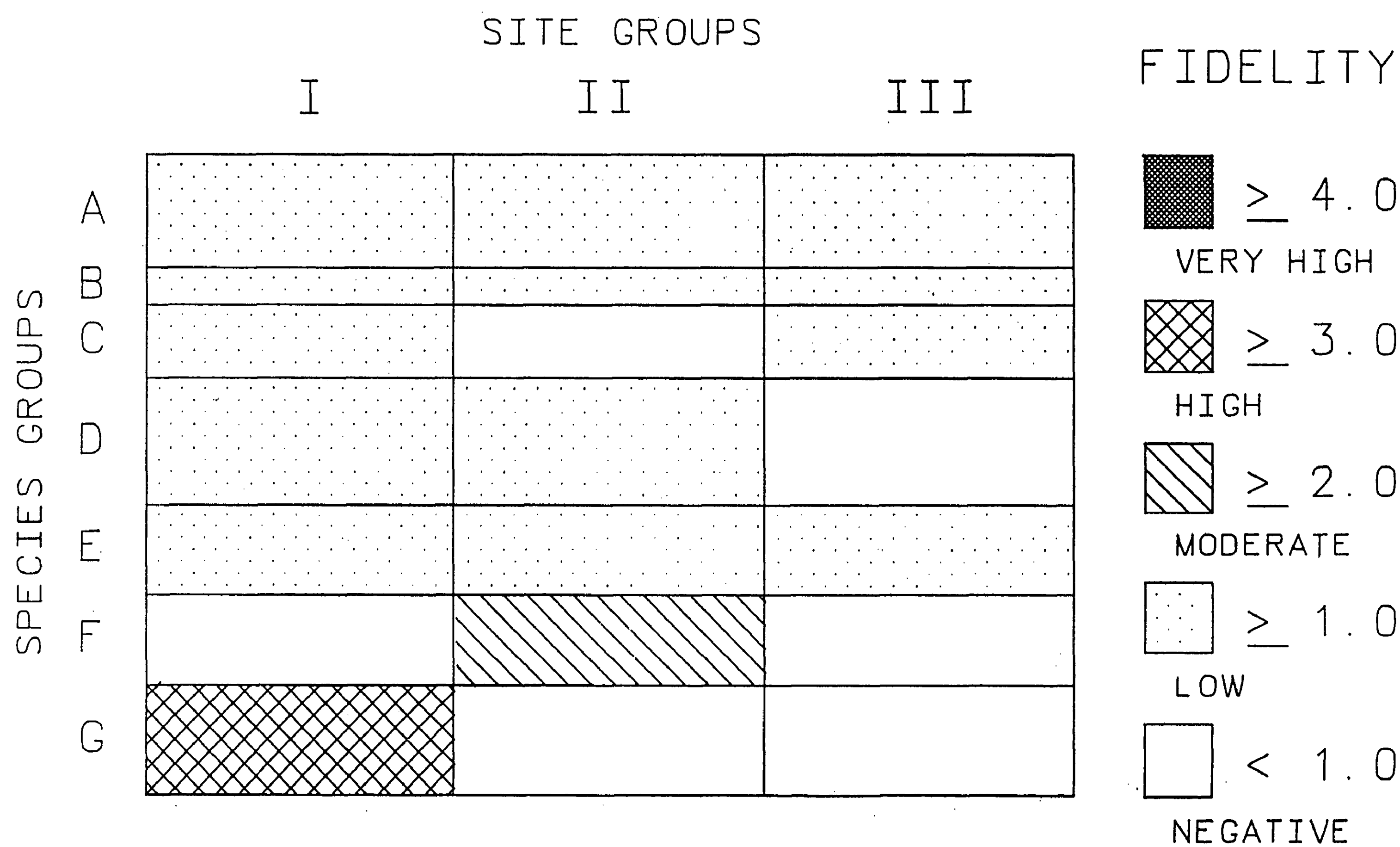


Figure 15(a,b). Nodal analysis of the species groups vs. the strata groups from the combined years Mattaponi cluster a) constancy index and b) fidelity index.



SITE GROUPS
I
II
III
SPECIES GROUPS
A
B
C
D
E
F
G
CONSTANCY
≥ 0.7
VERY HIGH
≥ 0.5
HIGH
≥ 0.3
MODERATE
≥ 0.1
LOW
< 0.1
VERY LOW

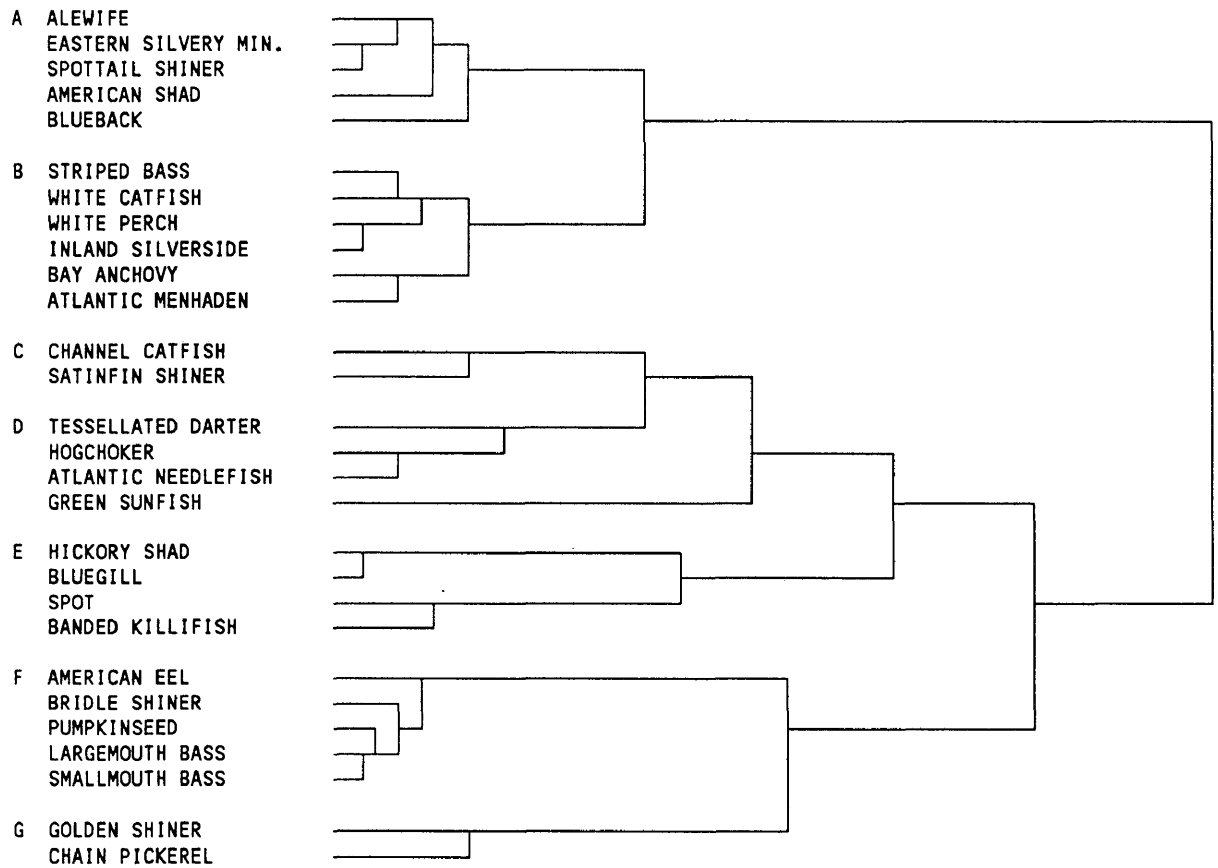
MATTAPONI


SITE GROUPS
I
II
III
SPECIES GROUPS
A
B
C
D
E
F
G
FIDELITY
≥ 4.0
VERY HIGH
≥ 3.0
HIGH
≥ 2.0
MODERATE
≥ 1.0
LOW
< 1.0
NEGATIVE

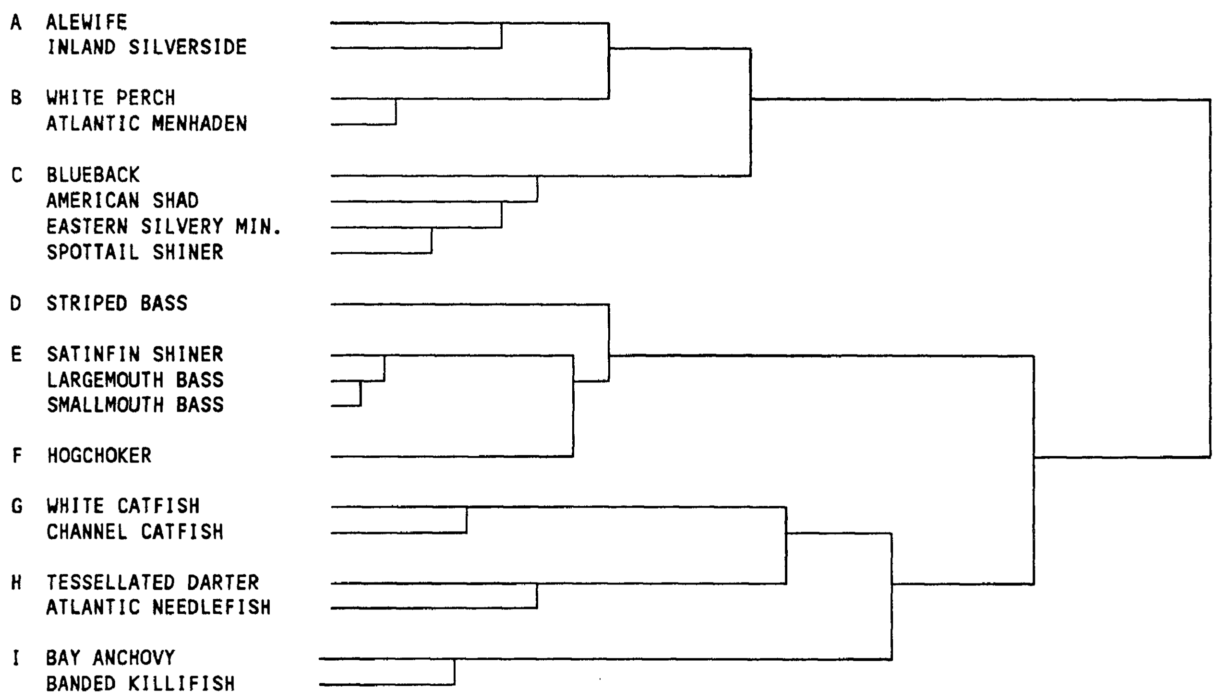
MATTAPONI

Figure 16(a-g). Dendograms of the species lists produced from the spatial cluster analysis for the Pamunkey a) all years combined, b) 1983, c) 1984, d) 1985, e) 1986, f) 1987, and g) 1991.

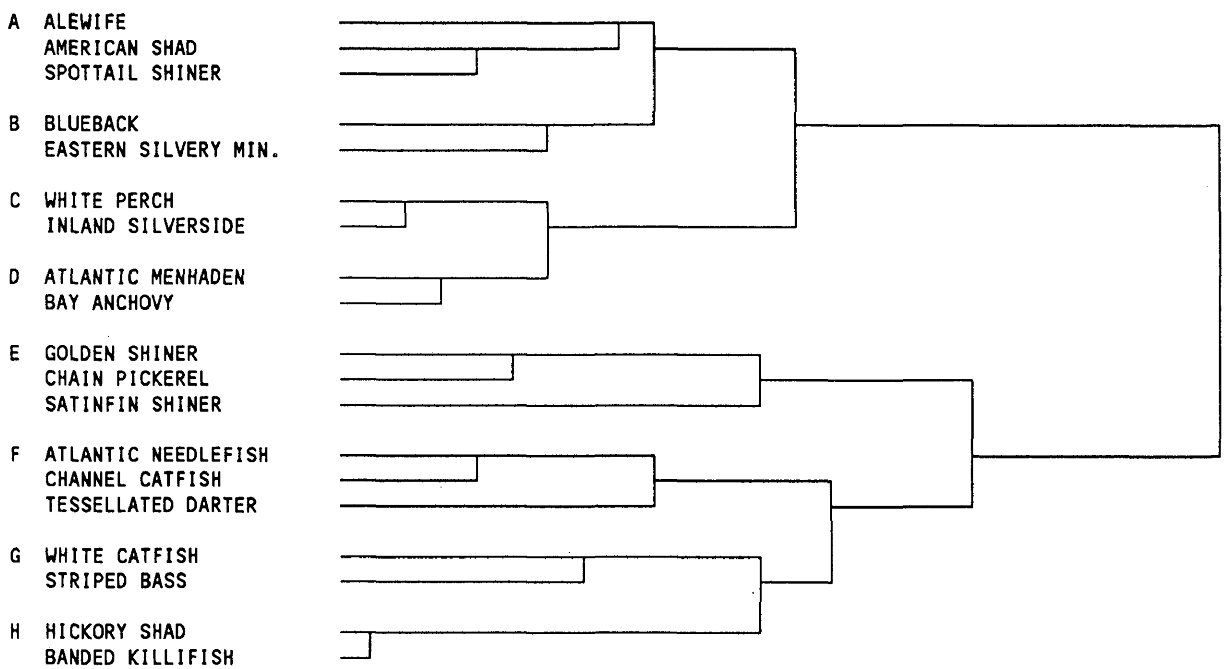
PAMUNKEY SPATIAL CLUSTER FOR ALL YEARS COMBINED CLUSTER BY SPECIES



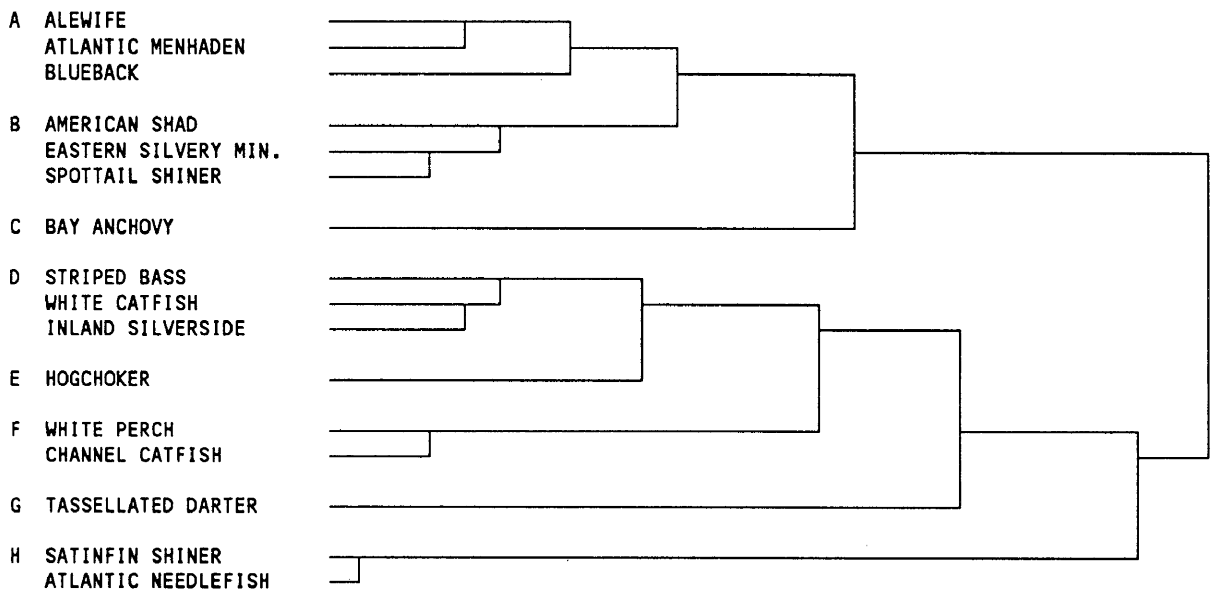
PAMUNKEY 1983 CLUSTER BY SPECIES



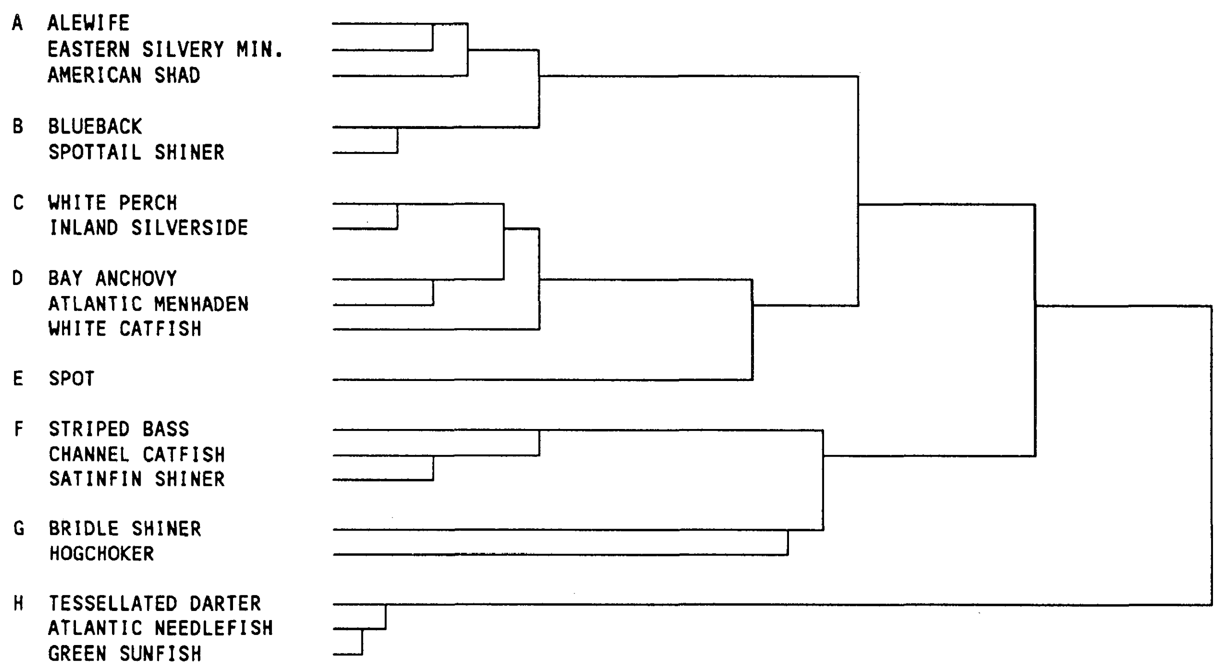
PAMUNKEY 1984 CLUSTER BY SPECIES



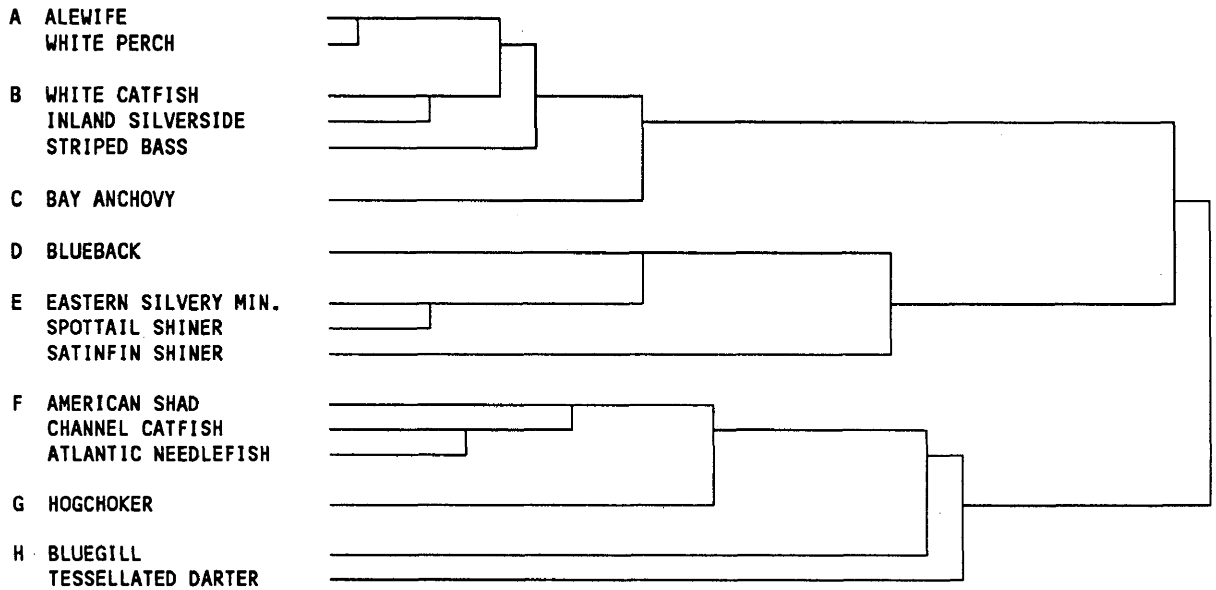
PAMUNKEY 1985 CLUSTER BY SPECIES



PAMUNKEY 1986 CLUSTER BY SPECIES



PAMUNKEY 1987 CLUSTER BY SPECIES



PAMUNKEY 1991 CLUSTER BY SPECIES

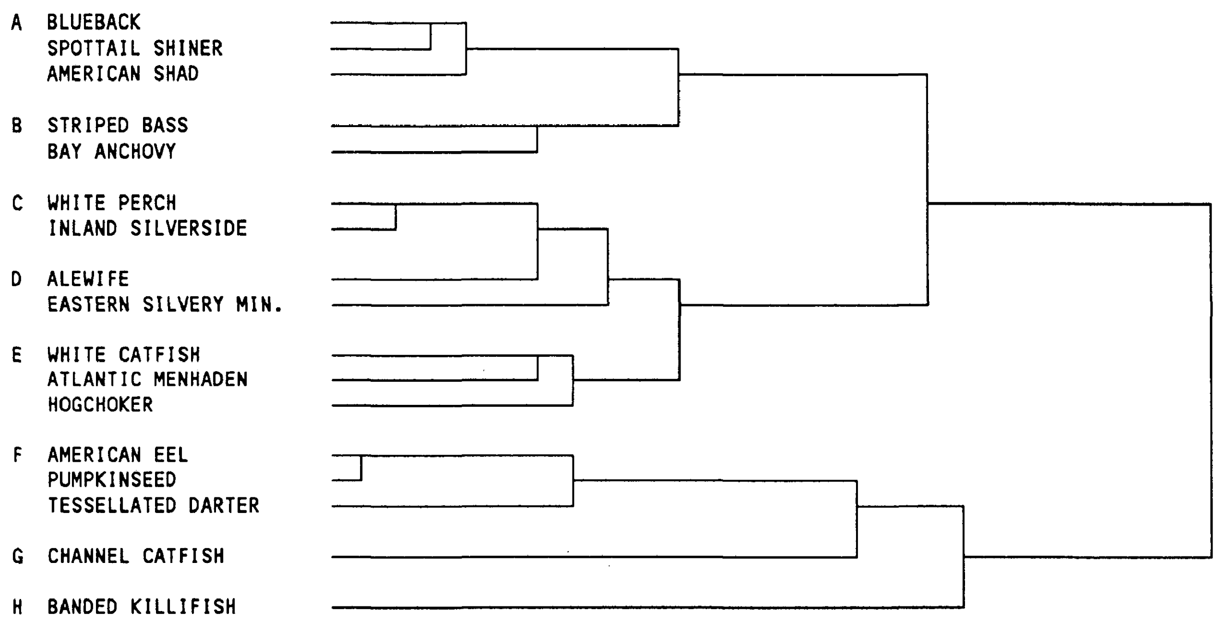
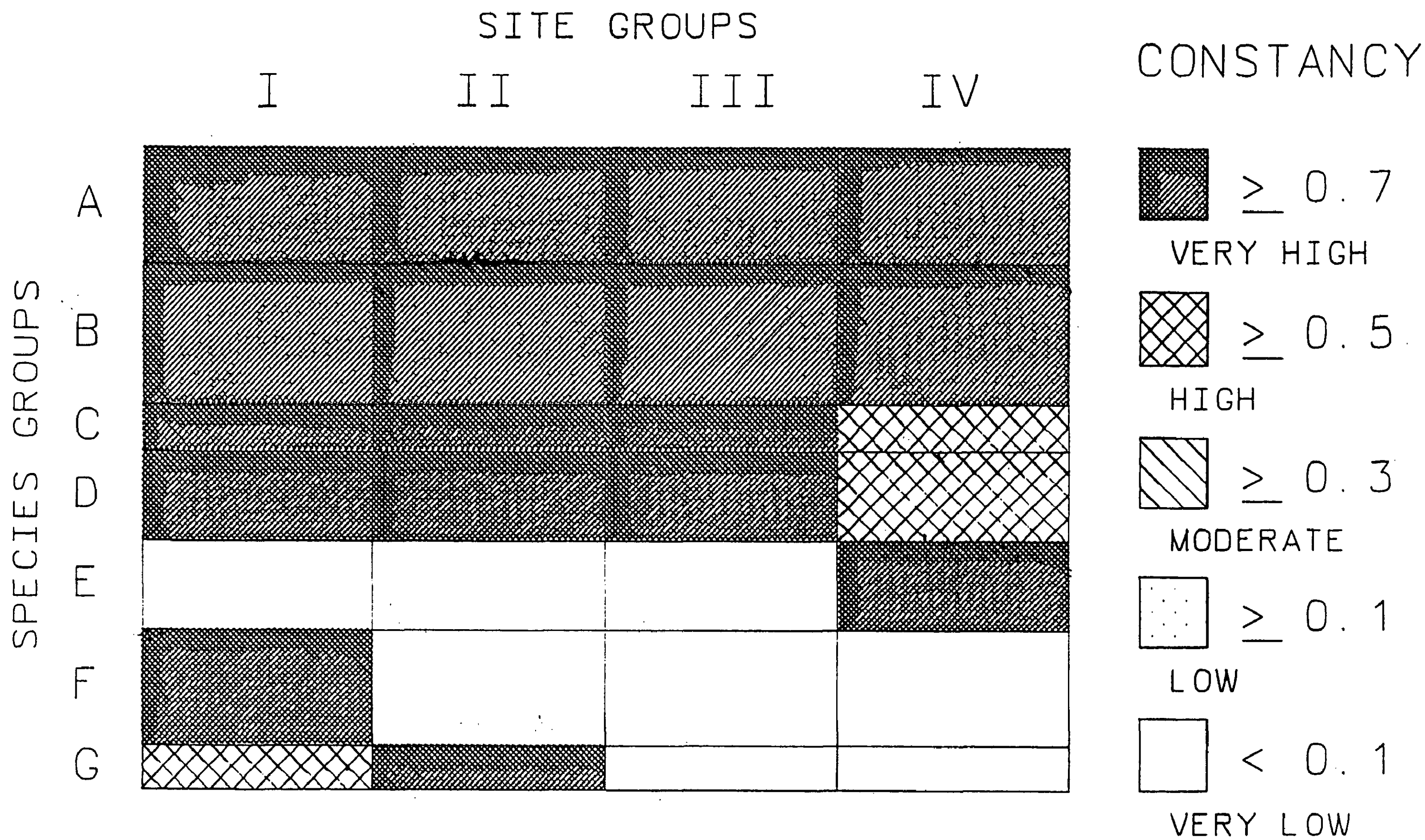
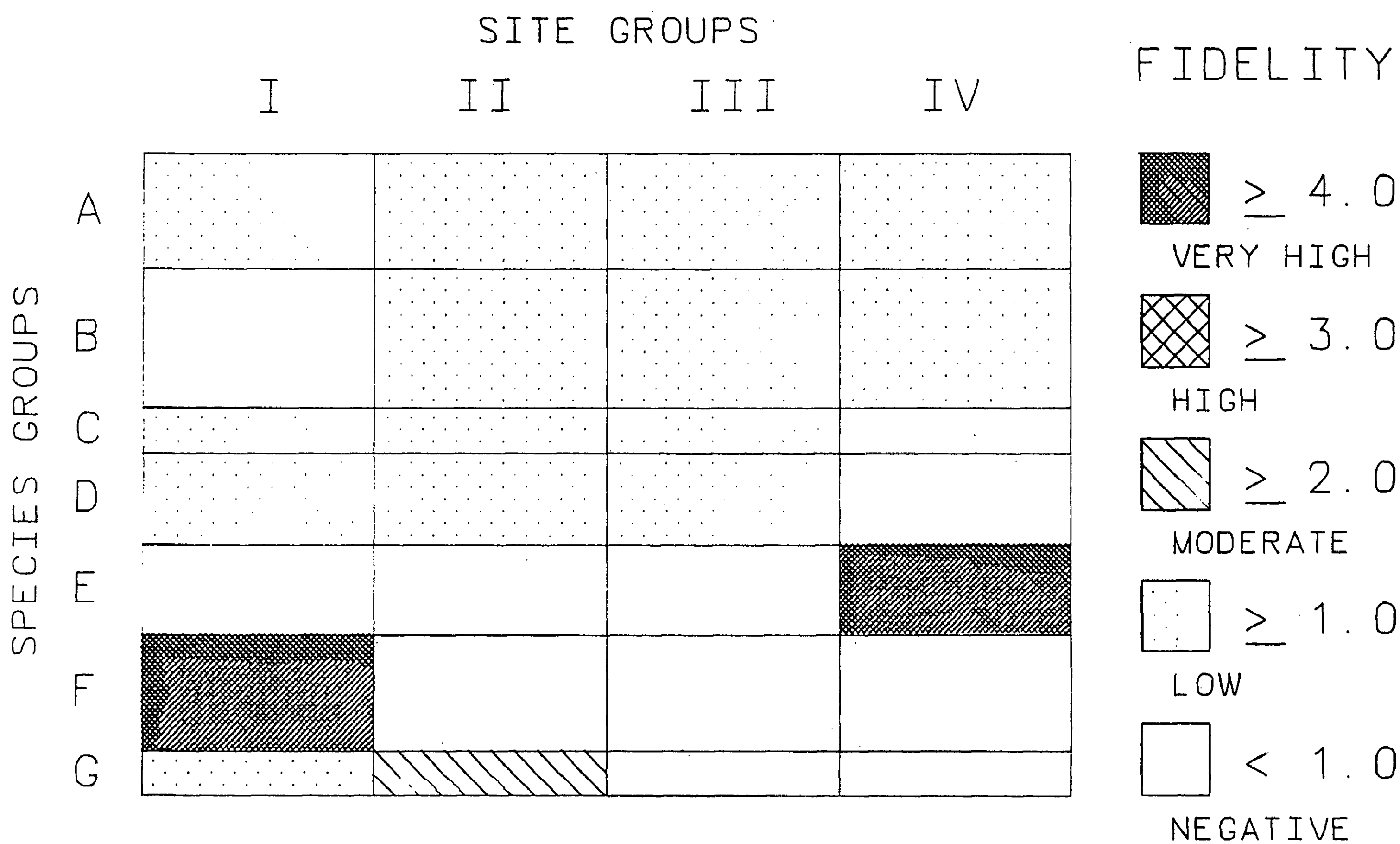


Figure 17(a,b). Nodal analysis of the species groups vs. the strata groups from the combined years Pamunkey cluster a) constancy index and b) fidelity index.


SITE GROUPS
I
II
III
IV
SPECIES GROUPS
A
B
C
D
E
F
G
CONSTANCY
≥ 0.7
VERY HIGH
≥ 0.5
HIGH
≥ 0.3
MODERATE
≥ 0.1
LOW
< 0.1
VERY LOW

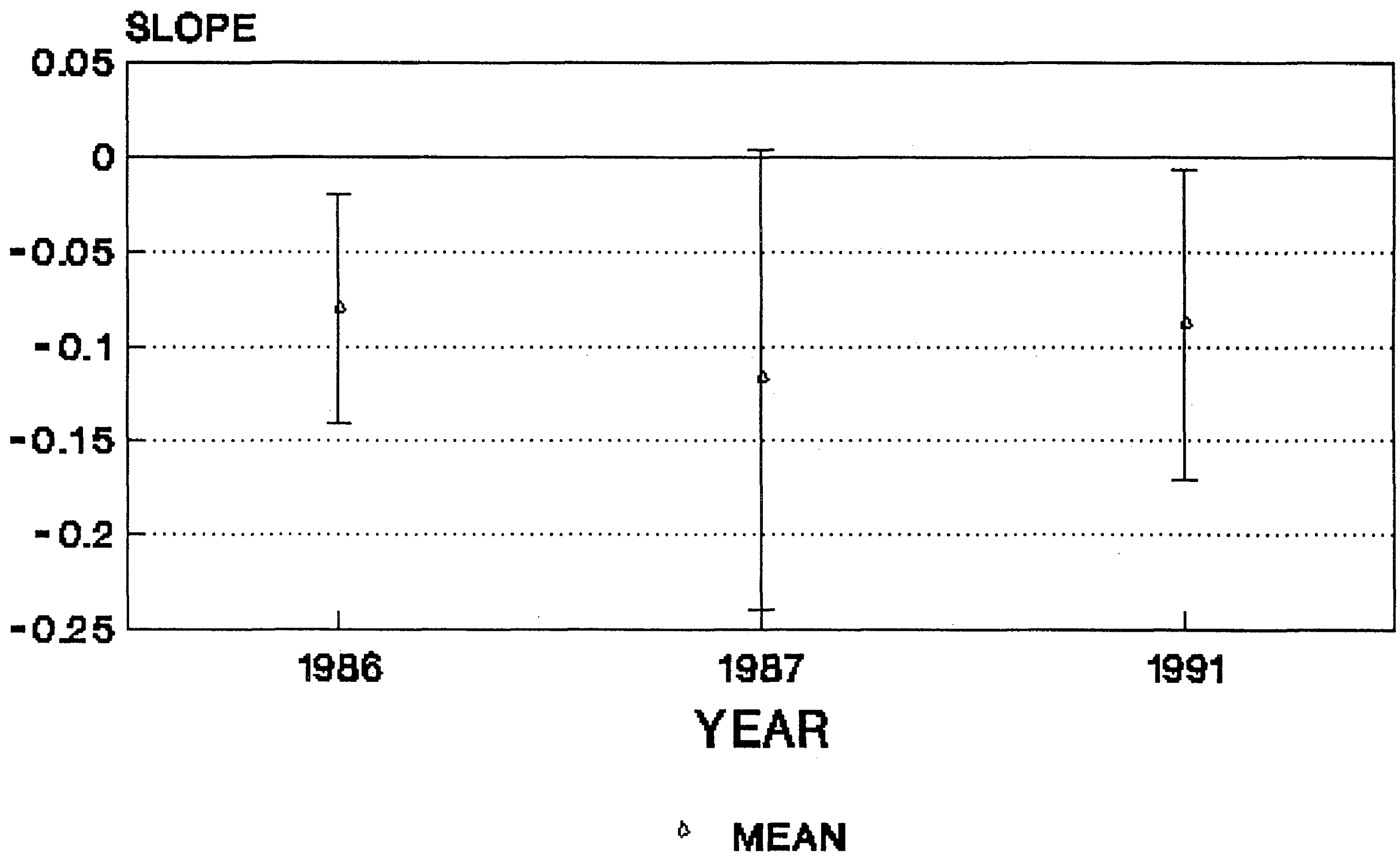
PAMUNKEY


SITE GROUPS
I
II
III
IV
SPECIES GROUPS
A
B
C
D
E
F
G
FIDELITY
≥ 4.0
VERY HIGH
≥ 3.0
HIGH
≥ 2.0
MODERATE
≥ 1.0
LOW
< 1.0
NEGATIVE

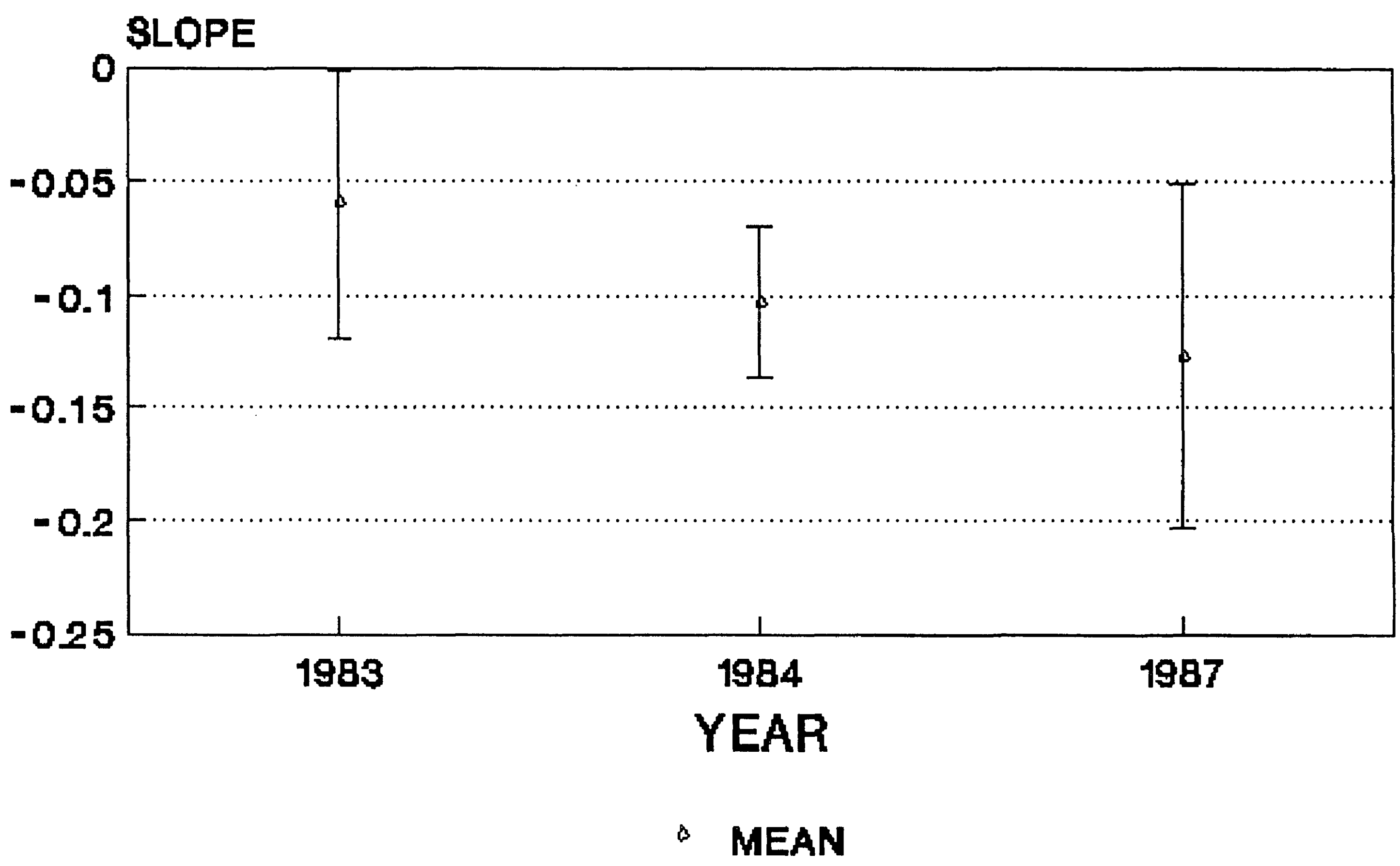
PAMUNKEY

Figure 18(a-c). Slopes ± their standard error ranges from significant logistic regression models that fit for the Mattaponi a) blueback, b) American shad, and c) Eastern silvery minnow.

MATTAPONI
Bluebacks



MATTAPONI
American shad



MATTAPONI
Eastern silvery minnow

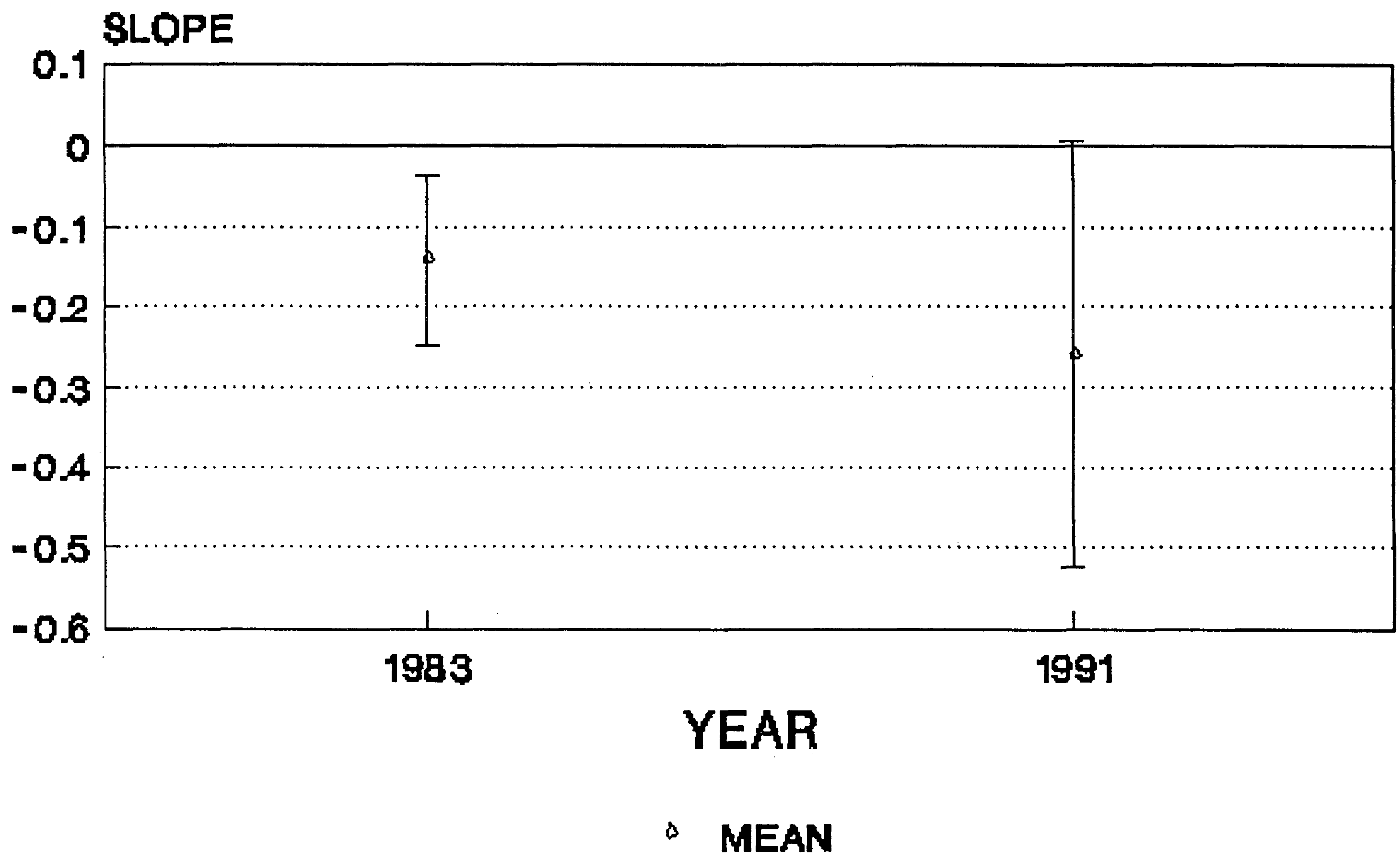
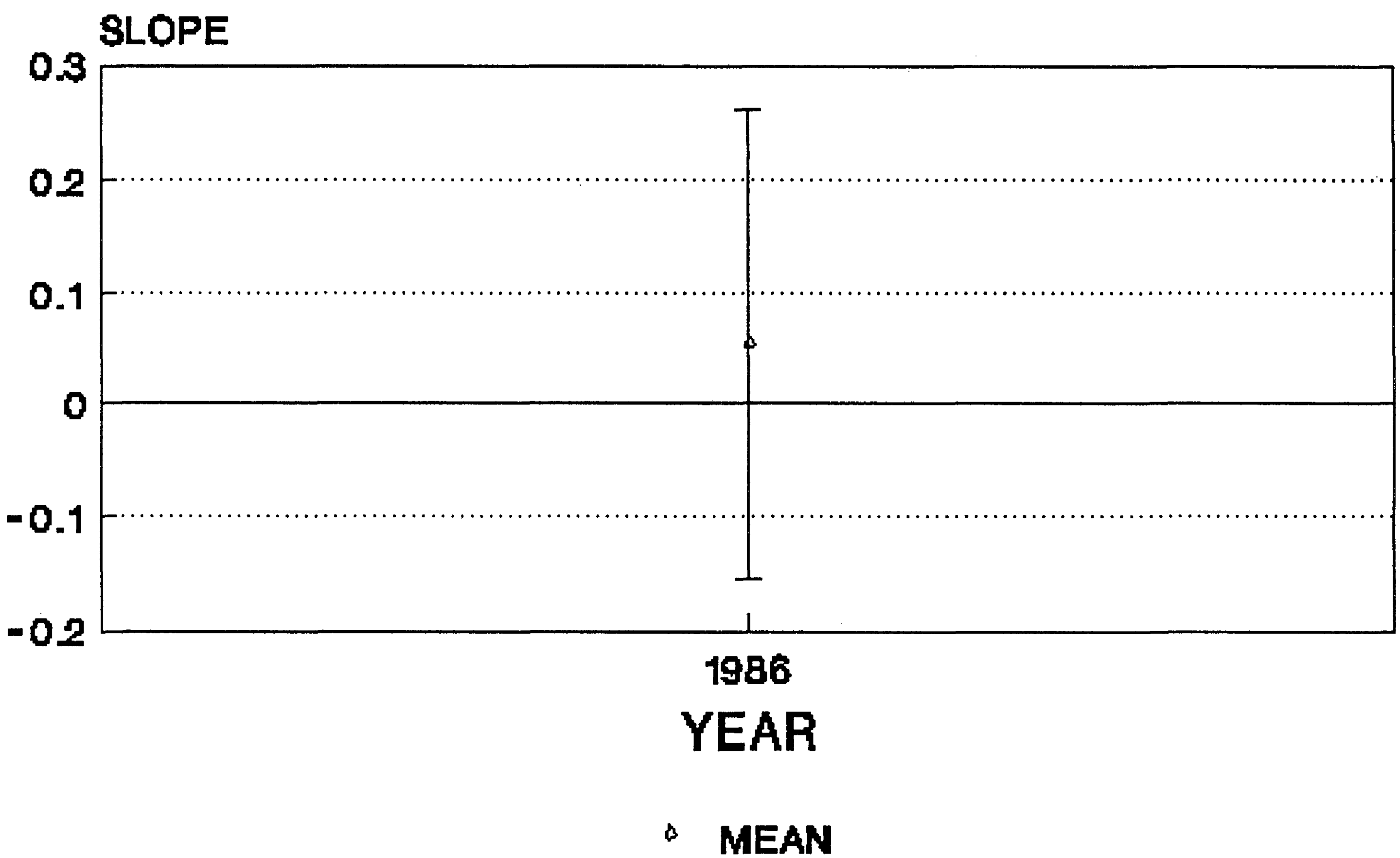


Figure 19(a,b). Slopes ± their standard error ranges from significant logistic regression models for the Pamunkey a) blueback and b) spottail shiner.

PAMUNKEY
bluebacks



PAMUNKEY
spottail shiner

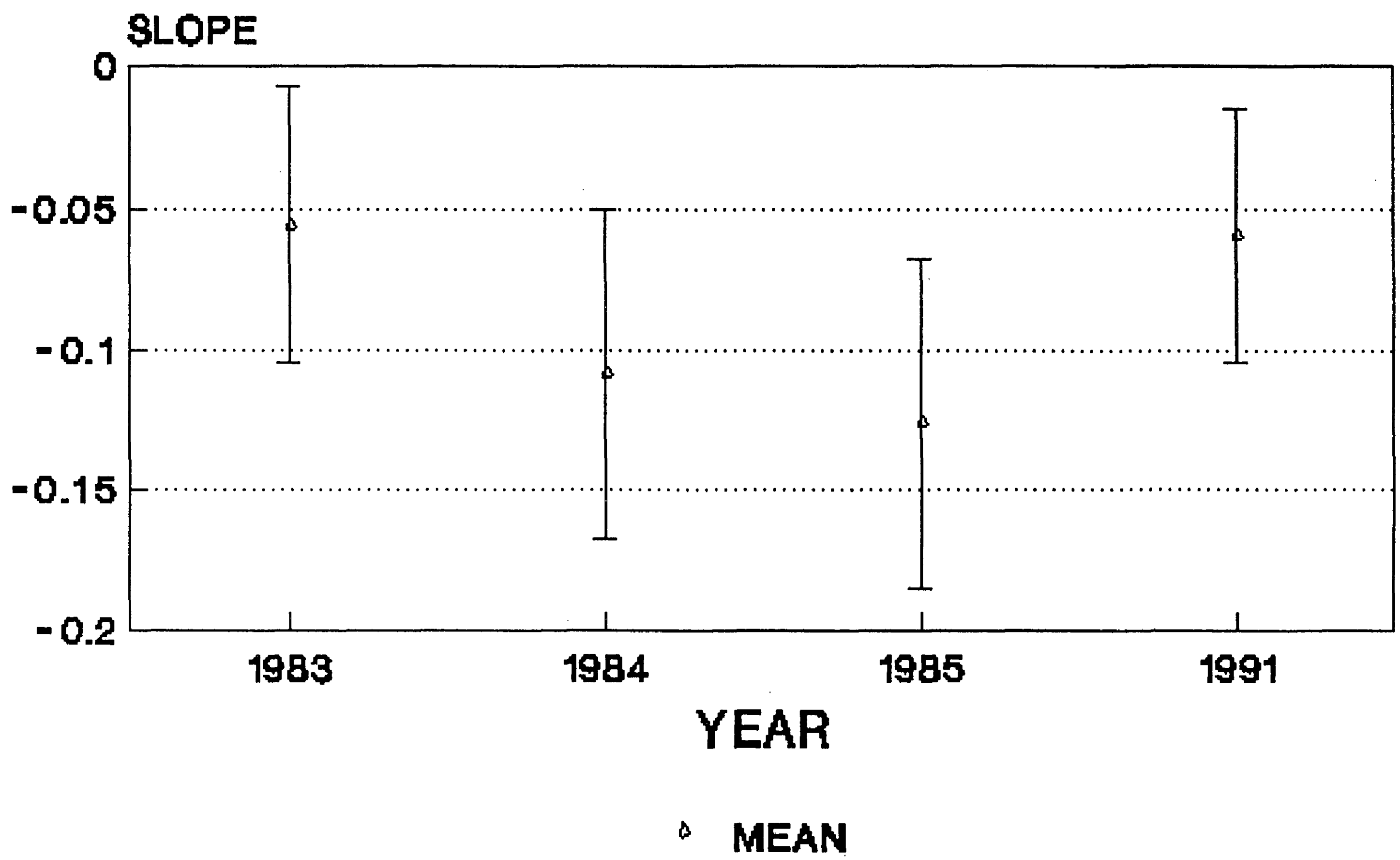
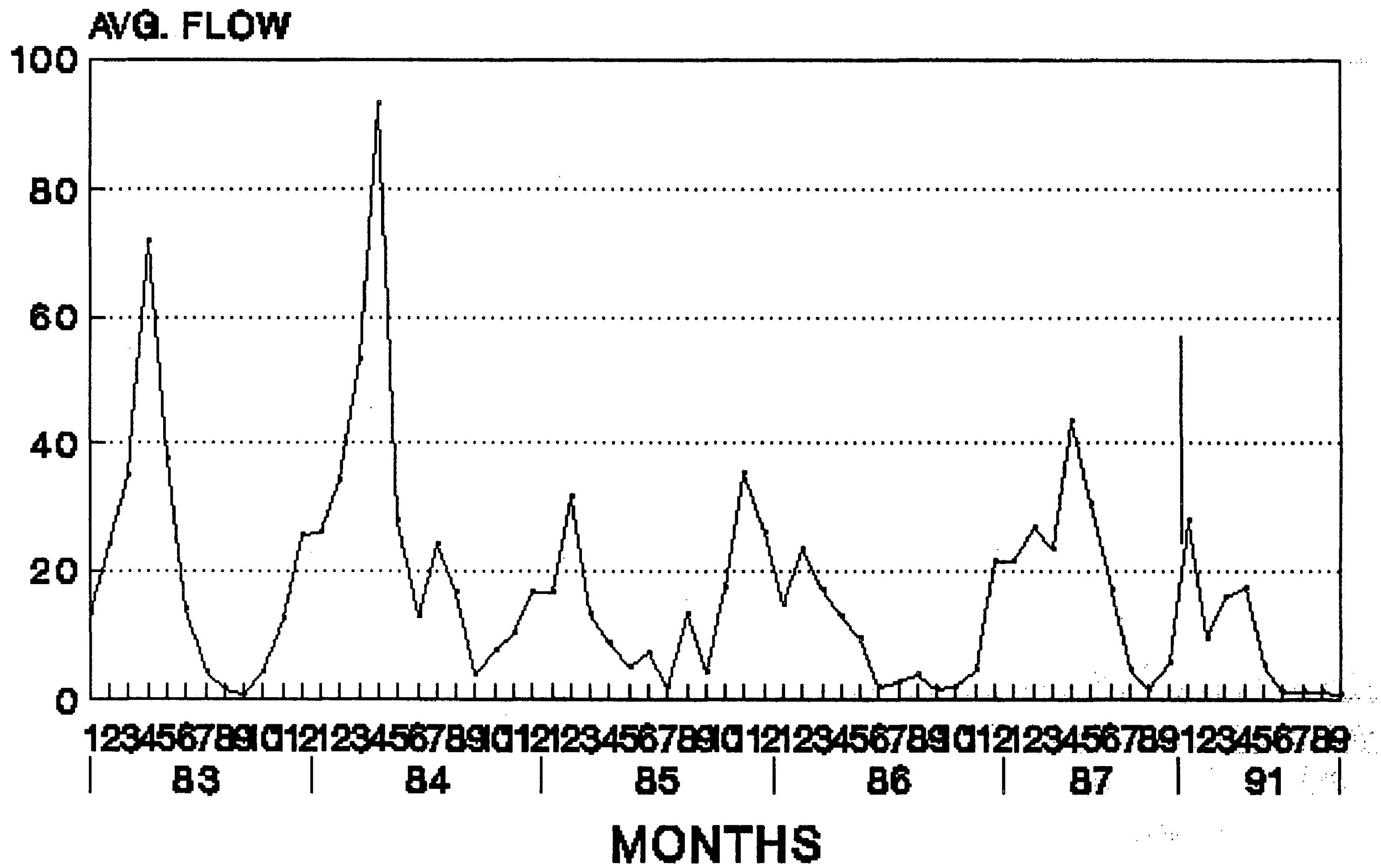
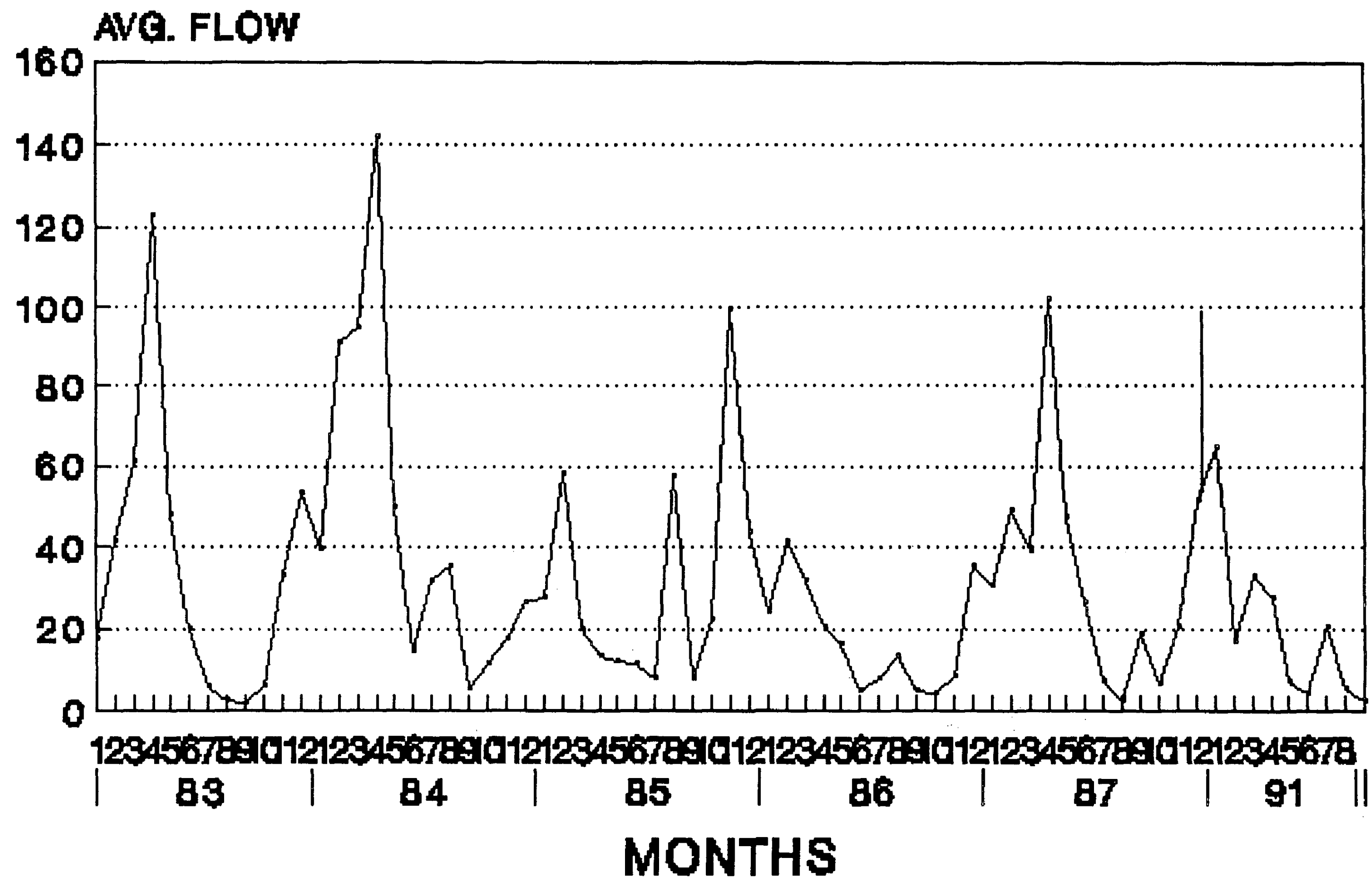


Figure 20. The average monthly flow rate for a) the Mattaponi and b) the Pamunkey recorded at the Walkerton station.

MATTAPONI FLOW
METERS CUBED/SECOND



PAMUNKEY FLOW
METERS CUBED/SECOND



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VITA

STEFFANY I. DAWSON

Born in Kankakee, Illinois, 18 March 1967. Graduated from Mehlville Senior High School in 1985. Earned a B.S. in Biology and a minor in Mathematics from Hope College in 1989. Entered masters program in College of William and Mary, School of Marine Science in 1989.